BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .1]

Subjects suggested for discussion by the Railway Congress,

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Figs. 1 to 13, pp. 923 to 934.

I. — The best section for rails.

In every rail distinction must be made between its two main parts : the part acting as a girder supported at a number of points, and the part provided to meet the wear caused by vehicles running over it. The first is composed of the section of height b and the latter of a (fig. 1).

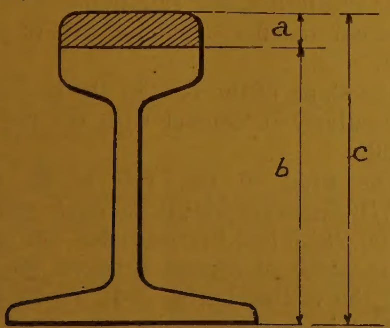


Fig. 1.

When the design of a rail is under consideration, part b must be first of all considered to see that it can carry within the elastic limit, even when worn down by a, the heaviest rolling loads allowed over the line.

The exact calculation of section b of the rail is very tedious as the ballast supporting the rails through the sleepers can yield.

As to part a, it is desirable the amount of metal needed, and the form it should take, should be so calculated as to reduce wear to a minimum.

The amount of metal in the whole section should be such that when the part included in a is worn away, the loss by the rusting of the other important parts, such as the foot and the web, should have reached its maximum. If this is not so, it may happen that part a has worn away whilst the foot and web are still in good condition, which means that had some metal been taken from these two parts to reinforce part a, the rail would have given longer service.

If a line with little traffic in a wet cli-

mate is concerned, the thickness of the foot and the web will have been reduced by oxydisation to the allowable minimum, whilst the part *a* is still far from the extreme limit of wear.

With a rail weighing 42.5 kgr. per linear metre (85.67 lb. per yard) the part *a* is usually made 15 mm. (19/32 inch) thick.

Many Engineers favour a perfectly flat rolling surface joined to the vertical faces of the rail by very small radii.

Rails with this rolling surface after some service take the form shewn in chain dotted lines in figure 2, that is to say, the metal of the rolling surface undergoes a kind of lamination at right angles to the rail.

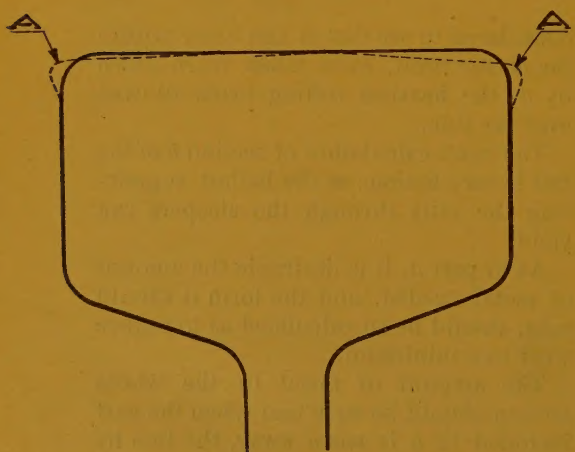


Fig. 2.

When the rails are laid on the straight, the deformation of the rolling surface is as shewn in figure 2. If the line is on a curve, the metal is displaced towards the outside of the rail only.

The metal displaced towards the outside of the rail eventually comes away in flakes, and this flaking away results in the surface of the rail diminishing at an increasing rate.

With rails with a convex instead of a flat rolling surface, connected by 9 or 10 mm. (11/32 or 3/8 inch) radii instead of 4 or 5 mm. (5/32 or 3/16 inch) to the sides, the phenomenon described above is not noticed.

During the latter years of their life, when the convex surface has been worn away and becomes flat, the same phenomenon is produced.

When the surface is convex, even though the metal under load is displaced on both sides of the highest point of the rolling surface, the metal does not extend past the head, and consequently does not disappear in the form of flakes. In this case the metal is reduced te powder by rubbing, and therefore the wear is much slower and the life of the rail longer.

Another cause of premature wear of the rail head with a flat rolling surface is that the rubbing between the tyre and the rail is not only due to rolling, but also to slipping. In fact, as the tyre is coned and in contact with the rail the length of a line across it, the path of the different points along this line across the frustum of cone cannot be the same during a complete revolution, the said points being at different distances from the axis of rotation.

The slope of the tyre in the part more particularly in contact with the rail is 1 in 20.

The head of the rail is 62 mm. (2 7/16 inches) wide; if the outer radii of 5 mm. (3/16 inch) be deducted, the minimum width of contact between the tyre and the rolling surface will be 52 mm. (2 1/16 inches) across the tyre.

The difference between the largest and smallest diameters will be $\frac{52}{20} \times 2 =$ 5.2 mm. (13/64 inch).

If we take a locomotive in which the

large diameter of the frustum of cone in contact with the rolling surface is 1.600 m. (5 ft. 3 in.), the diameter of the small end will be 1.5948 m. (5 ft. 2 51/64 in.). The difference between the paths followed during a complete revolution by the two points will be (1.600 — 1.5948) × 314 = 0.016 m. (5/8 inch).

During each revolution part of the tyre slips to a maximum extent of 16 mm. (5/8 inch).

The coefficient of slipping is in this case 0.20 and per contra the coefficient of rolling is 0.0007.

The destructive effect of slipping is about 300 times greater than that of rolling.

As the web connects the head to the foot of the rail, it is the part that has to take the slipping or shearing stresses, the maximum theoretical value of which is located in the plane through the neutral fibre. None the less I have never found a case of fracture through this plane : the fractures occur in the connection of the web to the head of the rail or to the foot. This fact shews that the thickness of the web should not be uniform, but that it should be strengthened at its connections with the head and the foot. This conclusion justifies the use of a rail profile having the faces of the web curved (concave) the minimum thickness being along the neutral axis.

The foot should meet the condition of giving maximum strength to the rail for a given quantity of material, with good stability.

The ratio between the foot and the height of the rail used to-day gives very good stability. The profile of the 42.500 kgr. (85.67 lb. per yard) rail has a 130 mm. (5 1/8-inch) foot and is 134 mm. (5 9/32 inches) high. The inclination of 1 in 20 to which the rail is laid ensures that the line of action of the weight of the wheels inclines towards the interior of the track which adds to the stability. If the weight of a wheel is 7 500 kgr. (16 535 lb) the moment which could be called the moment of stability will be (fig. 3) :

$$M = 7\,500 \times 0.076 = 570 \text{ Kg. M.}$$
(4 123 foot-pounds).

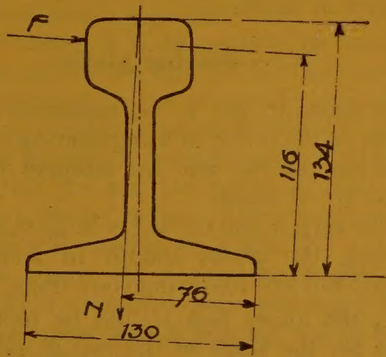


Fig. 3.

The overturning moment will be

$$M = 0.116\,F.$$

Taking F = 3 000 kgr. (6 614 lb.), a sufficiently high figure, the overturning moment will be :

$$M = 0.116 \times 3\,000 = 348 \text{ Kg. M.}$$
(2 516 foot-pounds).

This shews that, ignoring shocks and disturbances due to the dynamic action of the loads, we could do away with the coach screws holding down the foot on the inside without fear of any danger. This point will be dealt with when considering the bearing plates.

So far as the cross section of the rail is concerned, it can be affirmed that the width could be reduced a little and the metal so saved used to increase the height of the rail, so that it would offer a greater elastic resistance to the action of the vertical loads.

To sum up, the conclusion can be

drawn from the above review that the rolling surface of the rail ought to be convex, with a radius of curvature of about 200 mm. (7 7/8 inches); that the curves connecting the sides to the top of the head should be 10 mm. or 20 mm. (3/8 inch or 3/4 inch) radius, that the web should be bi-concave, and that the ratio between the height and the foot should be increased.

II. — Bearing plates.

It seems to me to be unnecessary to insist on the utility of using bearing plates between the rail and the sleepers when these are of wood.

The surface and thickness being suitably chosen, the plates should in addition satisfy the two following conditions :

1. the upper face should be inclined 1 in 20, the slope of the rail as laid in the track;
2. bearing ribs should be incorporated to prevent the canting over of the coach screws screwed through the outer side of the rails.

It is easier to make the rail seat in the sleeper horizontal than to cut it on the slope. Consequently the slope should be provided, not on the seat cut in the sleeper but, preferably, on the bearing plate.

It is frequently observed that the coach screws bend under the lateral thrusts, especially in the case of those holding down the outside of the rail on curves of small radius.

If the bearing plate has an outer bearing rib, as in the case of those made by Messrs. Krupp, when the coach screw bends its head butts against the said rib and further bending is prevented. The incidence of bent coach screws occurs more frequently and to a greater extent when bearing plates are not used.

Messrs. Krupp make plates with ribs on both sides. My opinion is that the rib inside the rail is useless : I have certainly never seen a bent coach screw in this position.

In general, bearing plates are drilled with three holes for an equal number of coach screws. Those plates with parallel bearing faces are usually laid in the track so that the coach screws are arranged alternately in different order : that is to say, if one of them is so placed that the two holes are inside, the next is laid with the single hole inside. Bearing plates with the upper face inclined have all to be placed the same way. If a distribution of coach screws like the first is wanted it would be necessary to drill half the plates with two holes in the lower part and the single hole in the upper, and the other half with one hole in the lower part and two in the upper.

The plates of this kind supplied by Messrs. Krupp had all the holes arranged in the same way : two in the lower part and one in the upper. I consider this distribution to be bad.

Speaking of rails, we have already seen that rolling loads gave rise to a considerable moment of stability. We have also seen that even when admitting a horizontal thrust of 3 000 kgr. (6 614 lb.) against the rail head, the overturning moment so produced was inferior to the moment of stability.

Let us see, before going further, if the value of 3 000 kgr. (6 614 lb.) for the thrust adopted above for comparison is normal or exceptional.

On straight sections of line, the lateral thrust exercised by the rolling stock running in these sections is insignificant. Nevertheless, further on I will quote an extraordinary case. It is often noticed that, on these straight sections, the gauge tightens after a time; in other words, if, after having had attention, the track is

exactly to the desired gauge, at the end of a certain time it will be found that the gauge has become tight at the level of the rail head. This is attributed to the inner edge to the foot of the rail under the action of the moment of stability being driven into the sleeper, which increases the inclination. This proves that the lateral thrust does not make itself felt.

Certain people attribute part of this phenomenon to the sleepers which, through not having been packed up for some time, finally bear on the ballast at the ends only, so that when trains run over them they bend: they straighten themselves, it is true, as soon as the rolling load has passed, but the repetition of this action results in some permanent curvature.

The facts, as I have been able to observe them, lead me to consider the first as the main cause.

We have already seen that on straight sections, the work done by the coach screws securing the rail foot on the inside of the track is very small. Whilst in these sections, it does not often happen that those holding down the part of the rail foot on the outside are greatly stressed, there are instances, such as the one I am now going to quote as I said before, in which the efficacy of these coach screws was put to a severe test.

A fairly light locomotive hauling an express train in running over a long straight section cut into the two rails at ten or twelve places, alternatively on each rail, and at almost equal distances apart.

The first and last cuts were slight, but the others were very serious : the coach screws on the outside of the track had been torn out leaving large gaping holes in the nearly new sleepers and were lying on the ballast.

On the other hand, not a single inside coach screw was found torn out. The reason the locomotive did not come off the line, in spite of the serious damage it did to the rails, was that the sleepers were newly laid and the rails were solidly fastened thereto.

This fact shews that in spite of the violent lateral blows the rails received, the thrust in shearing was greater than the overturning moment.

On curves, it is principally the lateral thrust against the outside rail that is felt. The increase in the resistance of a train passing through a curve is given a value which appears to be relatively low : 4 kgr. (8.8 lb.) per ton for curves of 250 m. (12 1/2-chain) radius : other authorities consider it should be 8 kgr. (17.6 lb.). If we take a wheel weighing 7 500 kgr. (16 535 lb.) the increase in resistance due to the curve would become $7.5 \times 8 =$ 60 kgr. (132.3 lb.).

Supposing that the whole of this resistance be solely due to the friction of the flange against the rail, the thrust against it, with a coefficient of friction of 0.2 would be $\frac{60}{0.2} = 300$ kgr. (661.4 lb.). With a coefficient of 0.1, the thrust would be 600 kgr. (1 322.8 lb.). This shews that the thrust of 3 000 kgr. (6 614 lb.) I adopted at the beginning does not err on the low side, and if, with such a high value, the moment of stability due to the vertical load is greater than the overturning moment due to the thrust, my theory, to wit, that it is more than sufficient if the part of the foot inside the track is fastened down with one coach screw only, is completely demonstrated.

Contrariwise, the coach screws on the foot outside the track have to resist the thrust of 3 000 kgr. (6 614 lb.).

The result of all this is that if we only take into account the static loads due to the loads of a train, from the point of theory alone, there seems to be no need to use coach screws inside the track, which

is the opposite to what has to be said about those placed outside it. Actually, the dynamic action of the moving loads gives rise to stresses which have to be absorbed by the track and make it necessary for both one and the other to be present and especially those outside.

Practice shews, more clearly even than theory, the difference in fatigue in the inside and outside coach screws.

On all curves of 300 m. (15 chains) or less, should the number of sleepers carrying the rail be insufficient, it is often noted that the rail moves towards the outside in spite of the resistance of the coach screws on this side : it frequently happens that the head of the inside coach screw is not holding down the foot, and that the edge of this latter and the head of the coach screw remain tangent to one another. The number of coach screws had to be frequently increased in the outside part of the rail corresponding to the large radius, to prevent displacement : on the other hand, I cannot remember that there has ever been any need to increase the number of coach screws on the inner side to hold down the rail on this side.

Conclusion: To improve the stability of the rail, the foot should be held down on the inside by means of one coach screw per sleeper and by two on the outside.

III. — Stability and length of sleepers.

When they are laid in the track, the sleepers are packed on the length corresponding to the rail bearing for about 25 cm. (10 inches) on each side of the rail centre. If we exaggerate it slightly, figure 4 shews how the sleeper is supported by the ballast.

If the bearings *ab* and *cd* would maintain themselves without the ballast spreading, or if we could be certain they would be repacked before this occurred, the length of the sleepers could undoubtedly be reduced to *ad*, which is 2.23 m. (7 ft. 3 3/4 in.).

I will say nothing about the utility of ballasting over the sleeper so as to increase its lateral stability.

What occurs in practice is that owing to the vibration due to the continual movement of loads over it, the ballast falls away, and ultimately the sleeper becomes supported along its full length. During tamping a certain compression has been exerted on the ballast in the zones *ab* and *cd*, and, in consequence, this part offers more resistance than the rest. In many cases, however, this is not so, as I will explain later on.

In the case shewn in figure 4, the way the sleeper functions is determinable; but when it rests on the ballast along the full length, the way it acts under rolling loads is not so readily calculated. Let us see if we can form any approximate idea of it.

Many writers agree that after it has been down some time the ballast becomes elastic, that is to say, it tends to return to its original state as soon as the loads producing the deformation are removed The coefficient varies between 3 and 8 kgr. per cm^2 (42.7 to 113.8 lb. per square inch) depending upon the quality of ballast used.

Let us take ballast of average quality with a coefficient of 5 kgr. (71.1 lb. per square inch).

Also let us suppose a sleeper 2.80 m. (9 ft. 2 1/4 in.) long, 13 cm. (5 1/8 inches) high, 24 cm. (9 7/16 inches) wide. Each rail transmits a load of 7 500 kgr. (16 535 lb.) to the sleeper, or a total of 15 000 kgr. (33 070 lb.).

The bearing surface is $280 \times 24 = 6\ 720$ cm^2 (1 042 square inches).

If the sleeper is supposed to be absolutely rigid, it will be depressed equally

along its whole length. To depress it uniformly 1 cm. (3/8 inch), a load of $6\,720 \times 5 = 33\,600$ kgr. (74 075 lb.) is required.

As the load is only 15 000 kgr., the uniform depression would be $\frac{15\,000}{33\,600} = 0.446$ cm., or approximately 4.5 mm. (5/32 inch).

The sleeper is not absolutely rigid however, far from it, and therefore is not depressed equally : it will sink most near the line of action of the concentrated load.

What can be affirmed is that the total quantity of ballast displaced will be the same in both cases.

The shape of the line of elastic deflection should be like that obtained if the sleeper were considered as supported at the points of loading and loaded uniformly its full length.

The uniformly distributed load per linear metre will be

$$\frac{15\,000}{2.8} = 5\,357 \text{ kgr. (3 600 lb. per foot).}$$

In this case, the equation for a girder free to deflect between supports b and c is the following :

$$y = \frac{pl^4}{\mathrm{EI}}\left[\frac{1}{24}\left(\frac{r}{l} - \frac{2r^3}{l^3} + \frac{r^4}{l^4}\right) - \frac{m^2}{12}\left(\frac{r}{l} - \frac{r^3}{l^3} + \frac{l-r}{l} - \frac{(l-r)^3}{l^3}\right)\right]$$

m being the ratio $\frac{l'}{l}$.

The deflection at the middle of the length bc is

$$f = \frac{pl^4}{\mathrm{EI}}\left(\frac{5}{384} - m^2\frac{6}{96}\right).$$

In our case, $$m = \frac{0.535}{1.73} = 0.309.$$

In order to design a girder which will be within the elastic limits, the analytical and graphical method due to Föppl may be used; as this procedure is very laborious and as we want relative and not absolute values, I think the case will be met if the girder is designed on the assumption that the sleeper is reversed, that is to say, supported on the bearing surface of the rails and subject to a load of 15 000 kgr. (33 070 lb.) uniformly distributed over the full length (fig. 5).

The bending at the ends a and d will be given approximately, though on the high side, by the formula $$f_1 = \frac{1}{8}\frac{pl'^4}{\mathrm{EI}}.$$

The value of the coefficient of elasticity E for English oak is, according to some authorities, 1 200 000 000 kgr. per m² (7.6 tons per square inch).

The moment of inertia of the sleeper is

$$\mathrm{I} = \frac{0.24 \times 0.13^3}{12} = 0.00004394$$

whence $$\mathrm{EI} = 52\,728$$

and $$f = \frac{5\,357 \times 1.73^4}{52\,728}\left(\frac{5}{384} - 0.309^2\frac{6}{96}\right) = 0.0064\ \text{m}.$$

The deflection at the middle of *bc* will be therefore about 6 1/2 mm. (1/4 inch). At the ends *a* and *d* the deflection will be

$$f_1 = \frac{5\,357 \times 0.535^4}{8 \times 52\,728} = 0.00104\ \text{m. (3/64 inch).}$$

Under the action of the rolling loads the sleepers take up a form like $a'b'gc'd'$ (fig. 6), the deflections being correspondingly smaller as the ballast coefficient is greater.

The pressure transmitted by the sleeper to the ballast will vary with the ordinates included between *ad* and $a'b'gc'd'$.

Let us see what will take place if the length of the sleeper were reduced to 2.60 m. (8 ft. 6 3/8 in.).

The bearing surface would be 260 × 24 = 6 240 cm² (967 square inches).

So that the line of the ballast be 1 cm. (25/64 inch) above the bottom of the sleeper, a load of 6 240 × 5 = 31 200 kgr.(68 783 lb.) is necessary.

As the load is only 15 000 kgr. (33 070 lb.), the sinking of the sleeper, taken as being absolutely rigid, would be given by $\frac{15\,000}{31\,200} = 0.48$ cm. or 4.8 mm. (5/32 inch). It will therefore be driven about four tenths of a millimeter (1/64 in.) further into the ballast than in the previous case.

Let us look into the distribution of pressure, taking the elasticity of the sleeper into account.

In this case, the uniformly distributed load per linear meter would be $\frac{15\,000}{2.6}$ = 5 769 kgr. (12 718 lb.) or in round figures 5 770 kgr. (12 720 lb.).

$$m = \frac{0.435}{1.73} = 0.251.$$

$$f = \frac{5\,770 \times 1.73^4}{52\,728}\left(\frac{5}{384} - 0.251^2\frac{6}{96}\right) = 0.0089\ \text{m. (11/32 inch).}$$

The deflection at the middle of *bc* will then be about 9 mm. (23/64 inch), that is to say, 2 1/2 mm. (3/32 inch) more than in the previous case.

The value of the deflections at the ends *a* and *d*

$$f = \frac{5\,770 \times 0.435^4}{8 \times 52\,728} = 0.0005\ \text{m. or 1/2 mm. (5/256 inch).}$$

In this case the pressure in the region of the rail supports will be greater than in the preceding case. The elastic part will of course not be represented by straight lines as I have shewn it in the drawing (fig. 7), but by curves, but straight lines are permissible seeing we are only trying to get relative values.

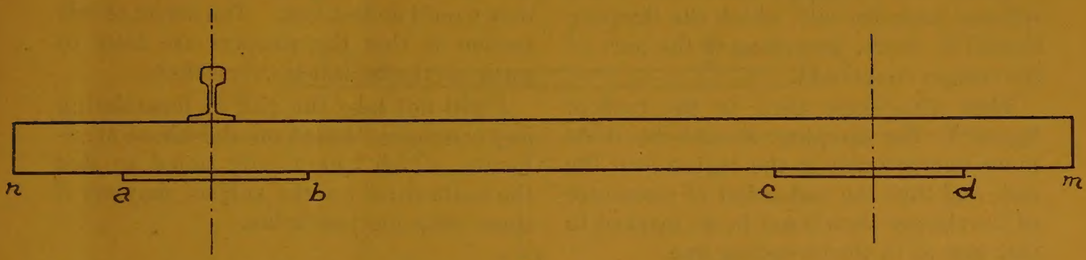


Fig. 4.

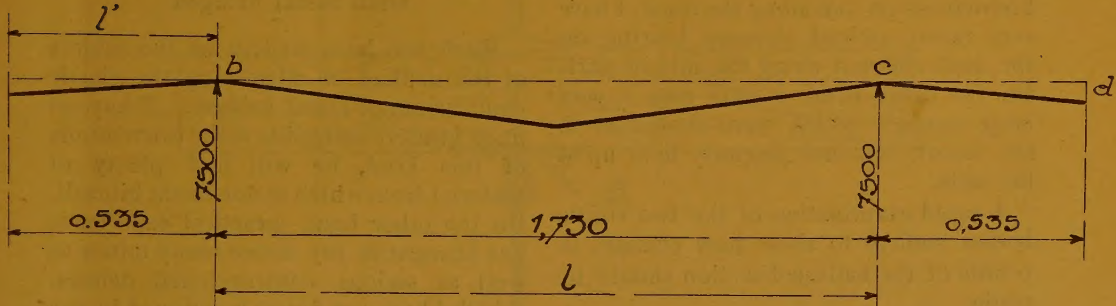


Fig. 5.

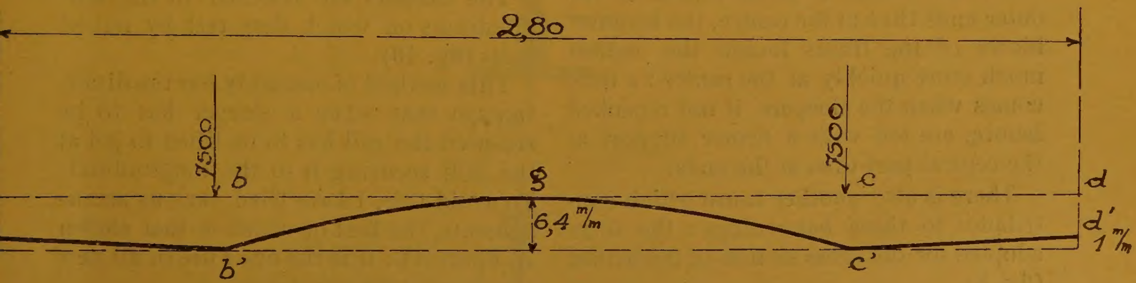


Fig. 6.

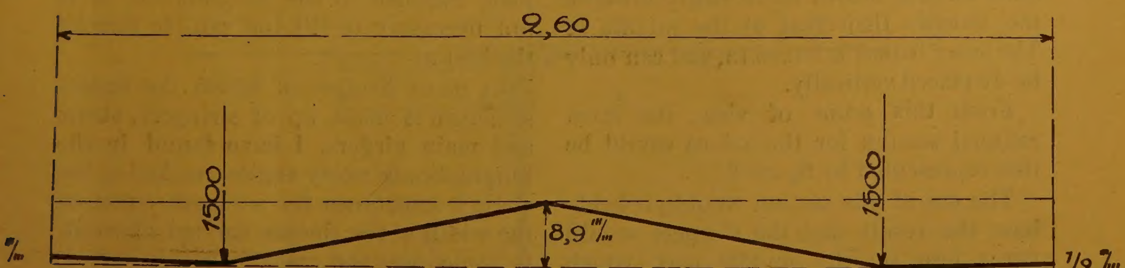


Fig. 7.

These two examples demonstrate the relative intensity with which the tamping should be done, according to the part of the sleeper concerned.

They also shew that, in the case of figure 7, the tamping should be done more energetically in the region near the rail, and that the reduction of resistance of the sleeper should not be so marked in this case as in the preceding one.

During the many tours of inspection I have made on foot along the track, I have very rarely noticed sleepers bearing on the ends and not along the middle part. On the other hand, I have seen a very large number which were supported at the middle and not properly held up at the ends.

A rapid examination of the two elastic bodies suffices to shew how changes in profile of the ballasted section should be made.

As the pressure which the sleeper transfers to the ballast is much higher at the outer ends than at the centre, the hammer blows of the trains loosen the ballast much more quickly at the centre : a time comes when the sleepers, if not repacked before, are left with a firmer support at the central part than at the ends.

There is also another cause which contributes to these happenings : the form adopted for the cross section of the ballast (fig. 8).

Under live loads, the ballast at the outer ends *a* moves more easily towards the outside than that at the middle *b*. The latter ballast is boxed in, and can only be displaced vertically.

From this point of view, the most rational section for the ballast would be that represented by figure 9.

The use of this section would probably have the result that the sleepers would never bear on the middle part, which would certainly lengthen their life because they would deflect less. The defect of this section is that the sleepers are freer to push up the ballast between them.

I will not take the risk of formulating any conclusion based on the above arguments, which I have only stated so that the authorities on the subject may say if these ideas are justifiable.

IV. — Some details in connection with metal bridges.

Much has been written on the subject of the method of calculating the elastic equilibrium of metal bridges. If anyone finds himself obliged to make calculations of this kind, he will find plenty of material from which to document himself. On the other hand, practical experience has brought to my notice many minor as well as serious constructional defects, which I have not found mentioned in any publication.

The sleepers are fastened to the longitudinals on which they rest by nutted bolts (fig. 10).

This method of assembly has the disadvantage that when a sleeper has to be renewed the rail has to be lifted to get at the bolt securing it to the longitudinal. To avoid this, I have tried various arrangements, the best of which is that shewn in figure 11 : it is the one I use in all new structures I have to design.

As the sleeper is bolted to a gusset plate attached to the longitudinal, it is not necessary to lift the rail, to remove the bolt *a*.

In many bridges of which the superstructure is made up of stringers, struts and main girders, I have found in the longitudinals many angles cracked at the angle *b* sometimes for a length equal to the width of the sleeper carried above it. In some cases the crack had just started,

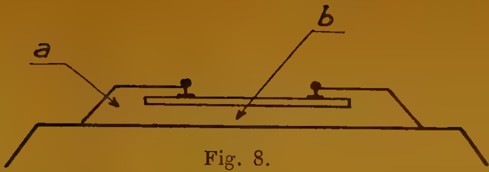


Fig. 8.

Fig. 9.

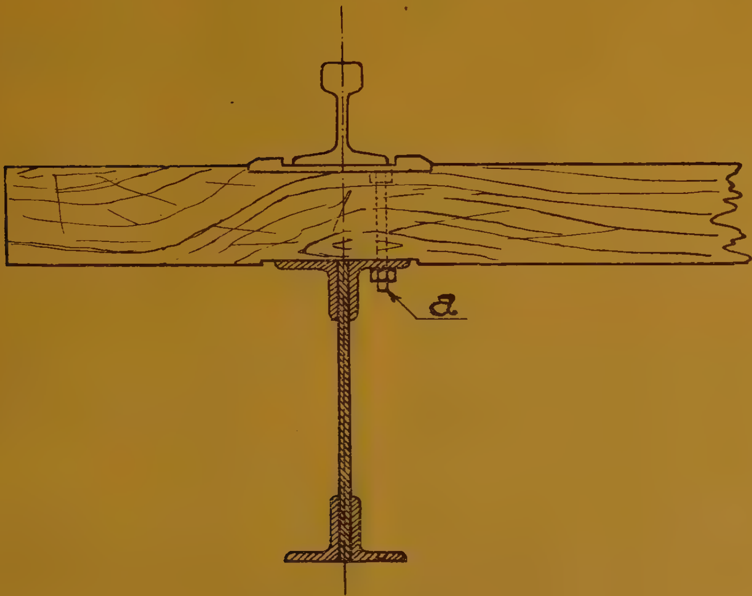


Fig. 10.

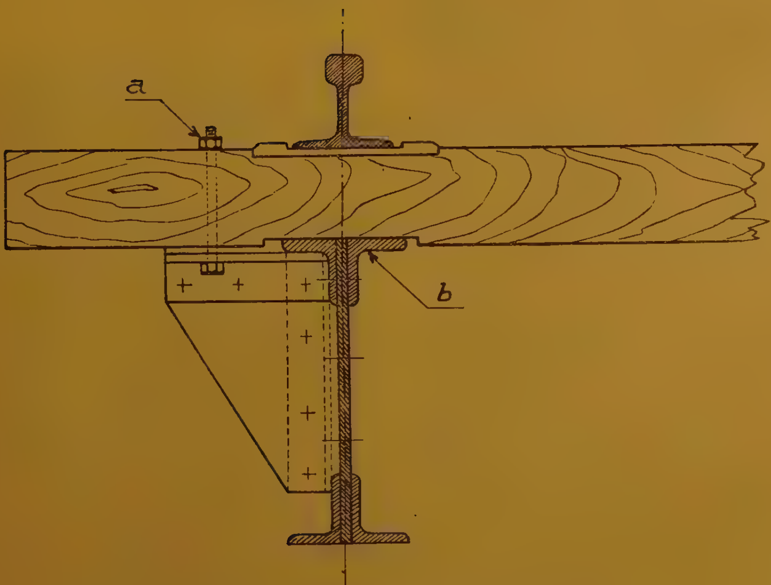


Fig. 11.

in others it was already of some length, and in the worst the length was, as I have said, equal to the width of a sleeper.

All the angles in which I have noticed this defect had equal sides.

The bridges to which these longitudinals belonged had been in service for more than forty years : they were all made of iron. It may be questioned if the same thing will occur in bridges built of steel. I should not like to give any answer to this question, although I think it would be as well to consider the point when getting out schemes for new metal bridges.

It is customary practice to strengthen the soles of the longitudinals by means of unequal angles, the longer side being horizontal, so as to give the maximum resistance for the least weight.

The fact mentioned above justifies unequal angles with the larger side horizontal being used when building up the longitudinals.

All metal bridges of small span have usually bearing plates of little thickness : 2 or 3 cm. (51/64 inch to 1 3/16 inches). Rain and condensation collect on the members : this water evaporates during the day and condenses in the lower part of the main girders (*a*, fig. 12) with the result that these parts rust prematurely.

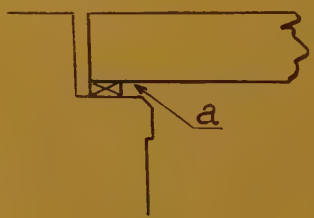


Fig. 12.

Owing to the thinness of the plates, it is difficult to scrape the part *a* just as it is difficult to paint it.

I have seen many bridges in which the plates of part *a* had almost disappeared through oxidation. To prevent it, I have used hollow plates, 10 cm. (3 15/16 inches) or more thick, which allow the pieces of part *a* to be scraped and painted.

Another defect observed in many bridges of small and large span is that the ends are built into the masonry (fig. 13) so that certain details can neither be scraped nor repainted. To meet this difficulty, the parts *abcd* and *a'b'c'd'* of the wall have been cut away.

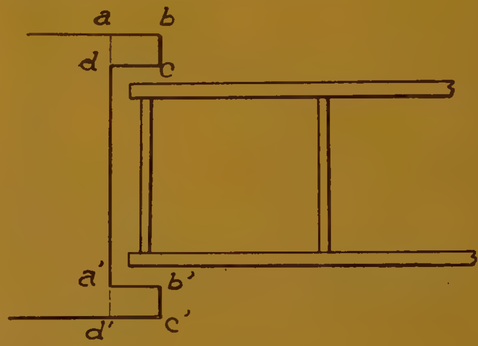


Fig. 13.

In many tie bars built up of riveted angles, spaced too widely apart, sometimes as much as 40 cm. (16 inches), the junction plates rust, the thickness of rust being about ten millimetres (3/8 inch). The distance between centres should not exceed 20 cm. (7 7/8 inches).

These small details can give rise to considerable trouble if they are not given sufficient attention.

[625 .154 (.44)]

Turntables for long wheel base locomotives used on the Paris, Lyons and Mediterranean System,

By Mr. HUBERT,

ENGINEER IN CHARGE OF ROLLING STOCK OF THE PARIS, LYONS AND MEDITERRANEAN COMPANY.

Figs. 1 to 22, pp. 938 to 953.

(*Revue générale des chemins de fer.*)

The turntables in use until recently on the Paris, Lyons and Mediterranean System, to turn long wheel base locomotives, could be divided into two groups :

1. Covered turntables : of high output, driven either by steam engine or electric motor : put down at the depots. The diameter is 20 m. (65 ft. 7 3/8 in.) or 21 m. (68 ft. 10 3/4 in.);

2. Open turntables : generally at marshalling yards where there is no depot, and hand driven by the two enginemen of the engine to be turned. The diameter is 23 m. (75 ft. 5 1/2 in.).

This essential difference in the methods of turning the tables gave rise to two equally different ideas on the design of the tables. Whereas the covered turntables are carried on a central pivot, and on rollers running on a circular track, which are carried on the foundations in turn, the open tables, at least whilst being turned, are supported on the centre pivot only, the balancing wheels being provided to come into use should the table tilt.

The result of these different methods of distributing the load on the pivot and the rollers or balancing wheels is that a much smaller turning moment is required to turn an open table than a covered table. Two men pushing directly on the end of the table, or on the locomotive itself, can turn it, which is quite impossible with a covered table.

The covered table is obviously more costly than the open type because of the flooring completely covering in the pit, and because the running gear and the track have to be made sufficiently strong to stand the heavy loads without deformation. Subsequently it was thought that the output of open tables might be increased by fitting them with suitable driving motors to make them suitable for use in same places as the covered tables.

Two different types of driving motors are employed, both in the form of small tractors attached to the table at one end.

One of these tractors runs on the same rail as the rollers of the table which it drives by the adhesion of its driving wheels on the rail, the other runs on a circular track independent of that of the table and exerts the necessary power through two wheels on a vertical shaft held against the edges of the head of the rail by springs.

Open tables fitted in this way gave the results expected in spite of having to

wedge the girders as engines come on and off the table, in order to prevent the violent tilting of the table, and to avoid the damage the resulting shocks would cause. This arrangement is a convenient way of increasing the output of existing tables or of using spare tables in places where high output is wanted : it is, however, neither the best nor the cheapest arrangement for new tables of high output. The open table, unlike the covered table, has to be wedged when engines come on it, the wedge released for turning, and the table wedged again when the engines leave it. This is a serious drawback and reduces the output if carried out, and if omitted is very prejudicial to the life of the table.

On the other hand, the girders of the table carried on the centre pivot alone have to be deeper than girders carried on the centre pivot and the rollers : the depth of the girder ought always to be kept to the minimum so that the pit may be as shallow as possible.

For these reasons the Paris, Lyons and Mediterranean Company has adopted for recent tables the type known as the bridge-table because the load is distributed between the pivot and the rollers, as with the covered table; whilst the pit, as in the case of open turntables, is not covered.

This table is 23 m. (75 ft. 5 1/2 in.) long, is arranged for motor drive, and can also be worked by two men who can easily turn the heaviest type of Paris, Lyons and Mediterranean locomotive.

The following table gives the comparative weights of a covered 21 m. [1] (68 ft. 10 3/4 in.) table, an open table 23 m. (75 ft. 5 1/2 in.) diameter with tractor, and a 23 m. (75 ft. 5 1/2 in.) diameter bridge-table :

Weight of 21 m. (68 ft. 10 3/4 in.) covered table with motor and runway.	93 000 kgr.	(205 030 lb.)
Weight of 23 m. (75 ft. 5 1/2 in.) open table with runway (metal and wood).	45 500 —	(100 310 —)
Weight of a tractor and coupling gear :		
a) using the table runway	7 500 —	(16 535 —)
b) with special runway and including the weight thereof.	5 500 —	(12 125 —)
Total (table and tractor) :		
Case *a*).	53 000 —	(116 845 —)
Case *b*).	51 000 —	(112 435 —)
Weight of a bridge-table electrically driven with runway . .	51 000 —	(112 435 —)

These figures shew that the 23 m. (75 ft. 5 1/2 in.) bridge-table is 42 000 kgr. (92 595 lb.) lighter than a 21 m. (68 ft. 10 3/4 in). covered turntable, and would be still lighter than a covered turntable of 23 m. (75 ft. 5 1/2 in.) if such a table existed.

The weights of a bridge-table and an open turntable fitted with a tractor are about the same. This is rather surprising at first sight, seeing that as the bending moments are reduced by supporting the girders at the ends and the centre, the depth of the girders can be reduced

[1] Maximum diameter in use on the Paris, Lyons and Mediterranean System.

considerably, and an appreciable saving in weight, even if not so great as that noted above, might be expected. The explanation is that the girders, being of little depth, have to be opened out at the ends so that the rollers shall not encroach on the loading gauge and to provide room for the hand or motor operating gear clear of this gauge. When to this is added the two sets of hand turning gear, the increase in weight absorbs the saving due to the less depth of the girders; on the other hand, the arrangement enables a thoroughly well designed turntable to be provided.

The object of the present note is to describe in turn the three types of table mentioned above :

Covered turntables;
Open turntables (with tractors);
Bridge-tables.

Covered turntables.

The Paris, Lyons and Mediterranean Railway uses two types of covered turntables 21 m. (68 ft. 10 3/4 in.) diameter.

The first type is the old table 14 m. (45 ft. 11 3/16 in.) in diameter enlarged, the driving gear which acted through an internal toothed ring being retained; the second, of more recent construction being driven by the adhesion of two driven wheels running on a circular track.

The few 20 m. (65 ft. 7 3/8 in.) diameter tables should be mentioned : they are old 14 m. (45 ft. 11 3/16 in.) diameter tables enlarged, and in construction are exactly like the 21 m. (68 ft. 10 3/4 in.) diameter tables enlarged from 14 m. (45 ft. 11 3/16 in.) tables in the same way.

Figure 1 shews a 21 m. (68 ft. 10 3/4 in.) covered turntable driven by gearing, and figure 2, one driven by adhesion.

In both types there is no load on the pivot when the table is idle. The weight of the rolling loads alone is distributed between the pivot and the outer rollers by the deflection of the girders.

The table is operated either by a steam engine or an electric motor with a steam engine in reserve.

In addition, one set of hand turning gear on the covered gear driven turntables, and two on those driven by adhesion, provide an additional standby, although even when a large number of men is used to work them, it is only possible to move the table slowly thereby.

The structure and the pivot of the two types of table are much alike in principle, as will be seen from figures 1 and 2.

The driving and running gear of the geared driven tables are sufficiently clearly illustrated in figure 1 to make it unnecessary to describe them further : a little more detail will be given of the driving and running gear of the adhesion driven tables which are of more recent construction, comparing them as necessary with the corresponding parts of the gear-driven tables.

1. *Track and running gear.* — The track for both types consists of a forged steel ring on which the rollers or balancing wheels run. This ring is bolted to a cast-iron bearing ring, bolted in turn to the foundation by foundation bolts. The under side of the steel ring is flat in both cases, but the upper side is a wide angle cone in the case of gear driven tables, and flat when driven by adhesion. This last arrangement was adopted to make it easier to machine and repair the runway. It entailed special construction for the rollers, as their axes are inclined on the horizontal plane and meet on the centre line of the table at the level of the runway.

Figures 3 and 4 shew the fitting of a motor driven wheel, the other carrying wheels being identical except that no spring is fitted.

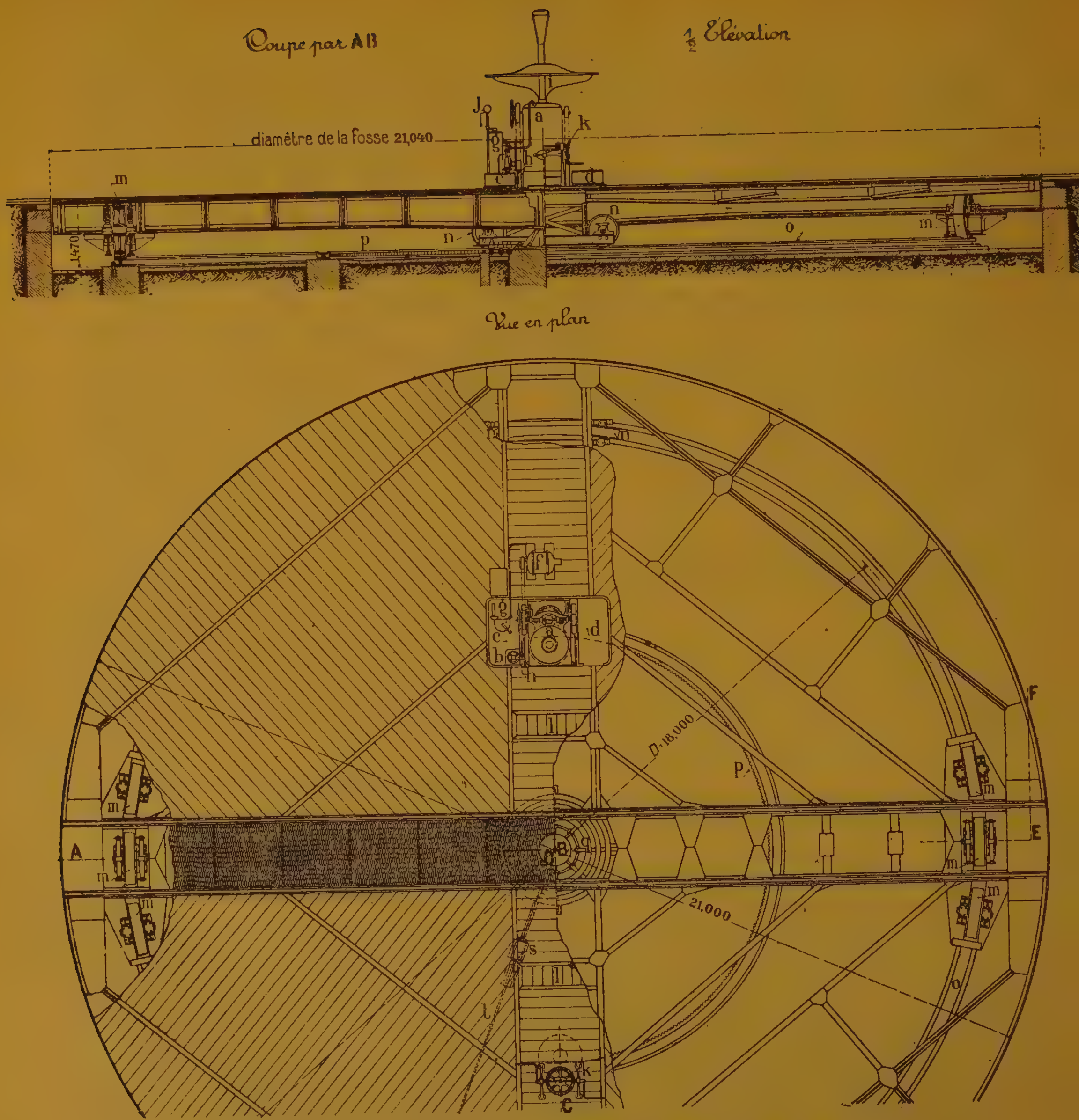


Fig. 1. — 21 m. (68 ft. 10 3/4 in.) covered turntable with gear drive.

REFERENCE :

a. Spare steam engine.
b. Injector.
c. Water tank.
d. Coal bin.
f. Electric motor.
g. Controller.
h. Brake pedal.
i. Shelter against rain.
j. Gong.
k. Spare hand turning gear.
l. Inspection trap doors.
m. Large carrying wheels.
n. Small carrying wheels.
o. Circular track.
p. Rack wheel.
q. Current collector rings.
r. Current collector shoes.
s. Cable junction box.
t. Supply cable.

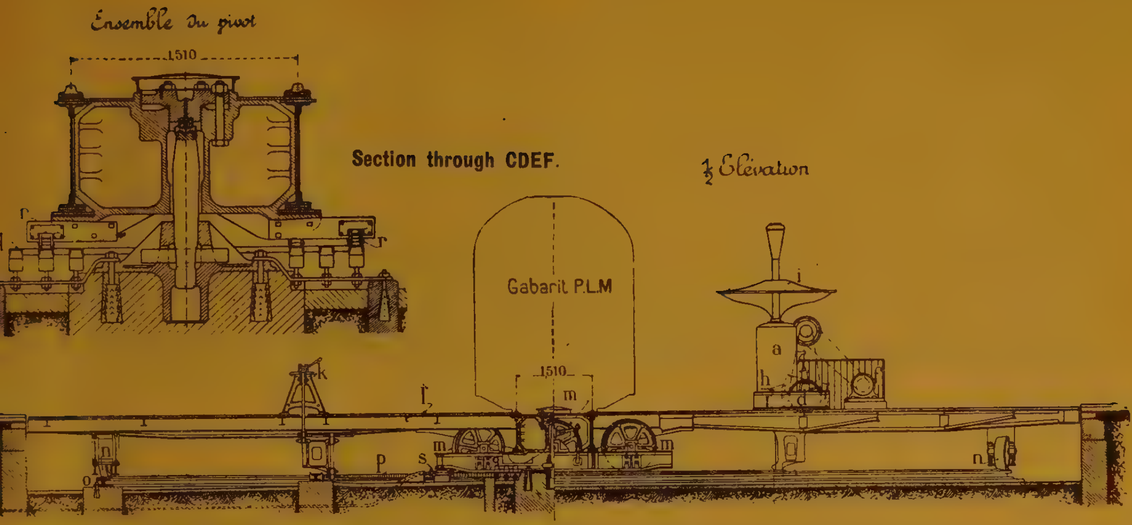


Fig. 1 (*continued*). — 21 m. (68 ft. 10 3/4 in.) covered turntable with gear drive.

planation of French terms in figures 1 and 2 : Coupe par AB = Section on AB. — Diamètre de la fosse = Diameter of the pit. — Ensemble du pivot = Arrangement of the pivot. — Gabarit P. L. M. = P. L. M. loading gauge. — Vue en plan = Plan. — ½ élévation = Half elevation.

2. *Driving gear.* — The two motor driven wheels are each placed at one end of the table on the centre line of the track (see fig. 2). The drive is transmitted to each of them by two symmetrical sets of shafts and gearing. A pedal brake, acting on a drum keyed to the intermediate shaft, makes it possible to stop the table exactly where required.

If the power drive be out of order, the table can quickly be got ready for hand working by meshing together the two pinions *k*, and taking the two pinions *l* out of gear so that the motor driving gear is not worked needlessly (see fig. 2).

Open turntables.

Figure 5 gives an idea of the general arrangement of these tables.

Structure. — The structure consists of two girders built up of plate and angles, the section at the centre being shewn in figure 6; these girders carry the bridge rails for the engines.

The girders are joined together at the centre and ends by bolted cast-iron stretchers, ten intermediate plate and angle stretchers maintaining the girders at the correct distance apart.

The central stay transmits the load to the pivot. Four cast-iron brackets placed at the end of the end stretchers carry the bearings of the balancing wheels. A platform of chequered plate makes it possible to walk about the table. The part of the platform between the main girders is carried on these girders and their cross stays; the part ouside them is carried on cantilever brackets made up from plate and rolled sections fastened to the girders. The platform has a railing along each side to prevent men from falling into the pit.

Pivot. — The pivot (fig. 7) consists of a bottom bearing in cast iron secured to the foundation by holding down bolts and carries the pivot pin itself. The pin is opened out at the top for the top bearing and bearing ring, both of case

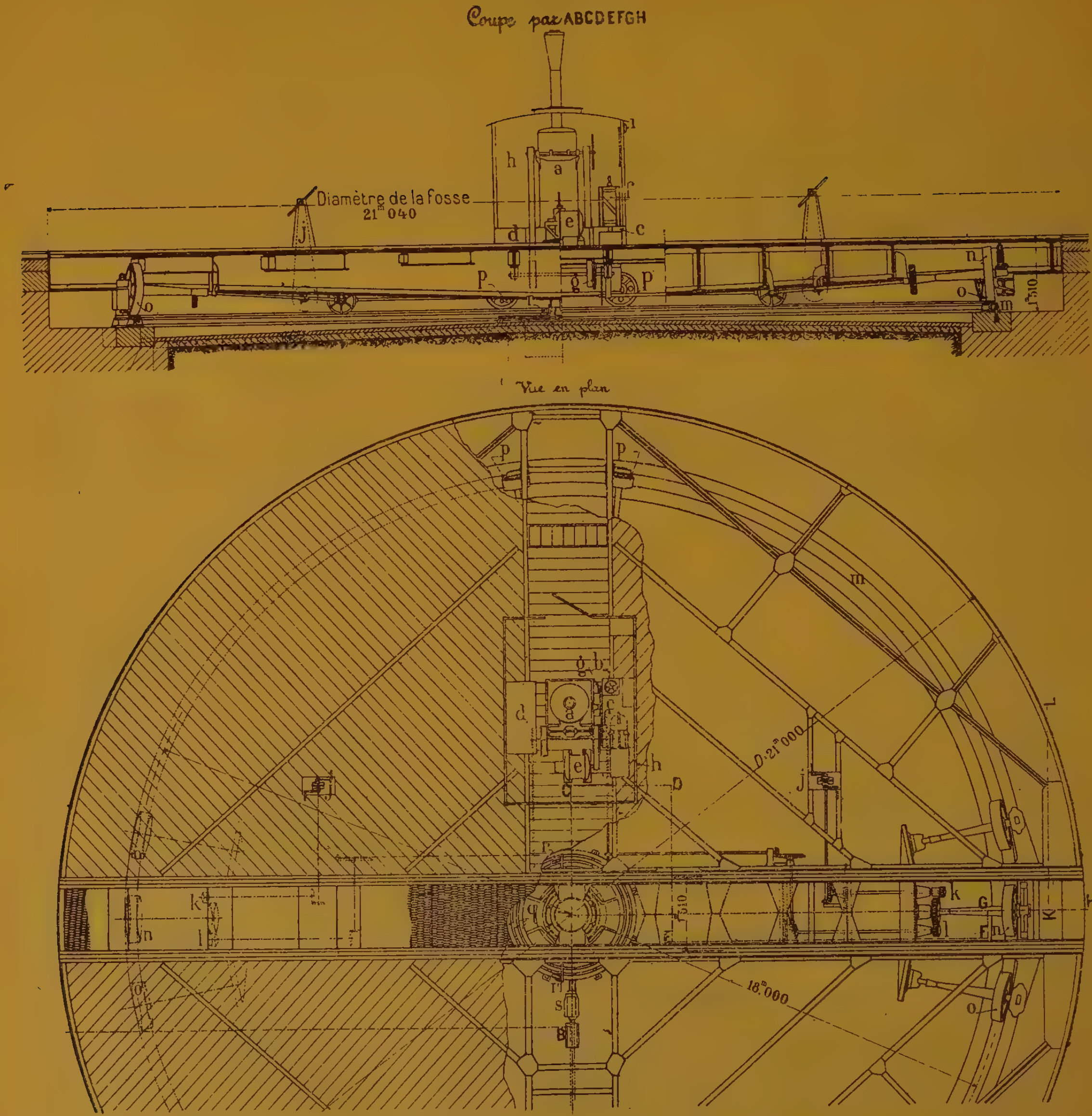


Fig. 2. — 21 m. (68 ft. 10 3/4 in.) covered turntable driven by adhesion.

REFERENCE :

- **a.** Standby steam engine.
- **b.** Injector.
- **c.** Water tank.
- **d.** Coal bin.
- **e.** Electric motor.
- **f.** Controller.
- **g.** Pedal brake.
- **h.** Glazed shelter.
- **i.** Gong.
- **j.** Standby hand turning gear.
- **k.** Sliding pinions for putting into gear the hand turning gear.
- **l.** Sliding pinions for putting into gear the electric driving gear.
- **m.** Circular track.
- **n.** Driving wheels.
- **o.** Large carrying wheels.
- **p.** Small carrying wheels.
- **q.** Current collector rings.
- **r.** Current collector shoes.
- **s.** Cable junction box.
- **t.** Supply cable.

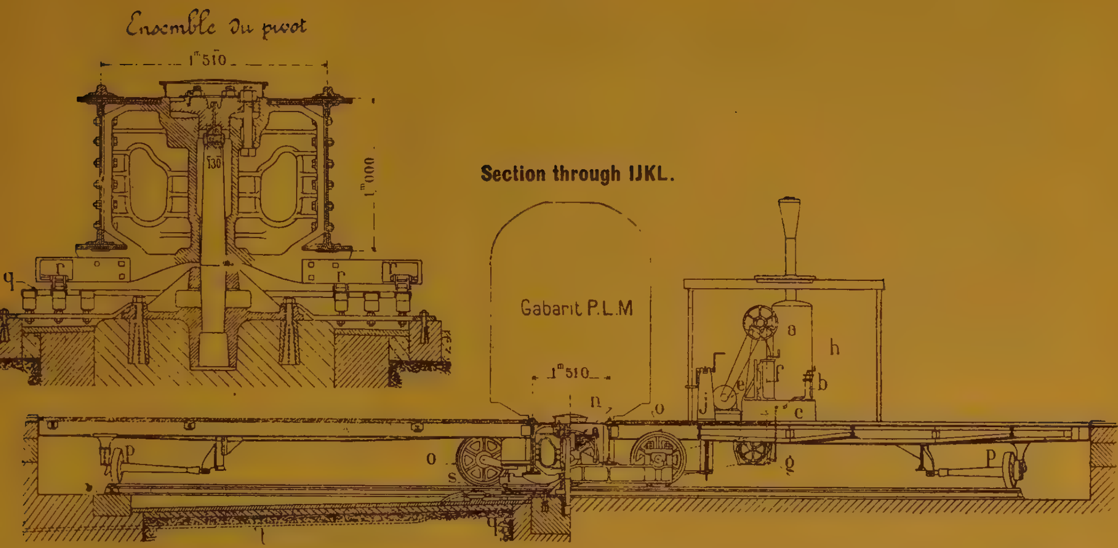


Fig. 2 (*continued*). — 21 m. (68 ft. 10 3/4 in.) covered turntable driven by adhesion.

hardened mild steel, and to provide an oil reservoir.

The bearing ring takes the load through a counter pivot in mild steel held in a cast steel cap from which the whole table is suspended by six bolts by which the level can be regulated.

The pivot takes the total weight of the table itself with the live loads. The balancing wheels are provided solely to prevent the table from tilting, and do not come in contact with the track whilst the table is being turned. Thanks to this arrangement, the driving power required to turn the table is reduced to a minimum, and as a matter of fact two men can turn the heaviest engine when placed with its centre of gravity above the pivot.

Locking the table. — The setting of the table in line with the track is assured by two locks at the end of the table in the centre of the track worked from the platform. The same levers are used as turning levers to push the table round.

Locking. — As the balancing wheels are clear of the track when the table is being turned, it is necessary that :

1. there should be some play, about 5 mm. (3/16 inch), between the balancing wheels and the track after the full deflection of the table under the heaviest locomotive;

2. the play be 20 to 25 mm. (25/32 to 1 inch) when the table is light, that is equal to that under *1.* plus 15 to 20 mm. (19/32 to 25/32 inch), the deflection of the girders under load.

This amount of play between the balancing wheels and the track would result in highly destructive blows when engines came on to the table unless something was done to diminish the effect.

For this purpose *four moveable locking bolts* are fitted under the ends of the girders. Two sets of hand wheel operated gear, each controlling the locks at one end of the table, are provided so that the locks may be inserted between the underside of the girders and the bearings provided for the purpose arranged suitably around the pit so as to limit the

play to 2 mm. (5/64 inch). The tipping of the turntable is in this way almost entirely prevented when engines are being moved, and the destructive effects of such tipping are in consequence avoided.

Circular track. — The track should in theory carry no part of the load when the table is being turned, or when engines come on to or leave the table. It consists of standard rails suitably bent and held by coach screws to wood sleepers.

Turntable tractors.

As stated at the beginning of this article, two types of driving gear are used on the Paris, Lyons and Mediterranean System to work the turntables, each in appearance like a small tractor coupled to an end of the table.

1. Tractor with horizontal adhesion surfaces.

(Figs. 8, 9 and 10.)

This tractor consists of a cast-iron frame connected by a built up extension of plate and angles to the table near the pivot.

An electric motor drives through a train of gear wheels an intermediate shaft carrying a claw clutch and a brake pulley. A pinion keyed to the intermediate shaft drives two gears keyed to the shafts of the two driven wheels which run on the same track as the balancing wheels of the table. Hand winding gear with two cranks enables the driving wheels to be driven through the claw clutch if the motor or current fail.

A double shoe brake, worked by a pedal, acts on the pulley on the intermediate shaft.

A jointed coupling shaft connects the tractor to the table near its end whilst allowing the table to tilt slightly about its pivot.

A shelter is provided to protect the machinery.

The operator remains in the shelter and stands close to the levers operating the stops and the latch and lock at the corresponding end of the table; he can operate them without leaving his post.

Current is collected by three slippers sliding on three concentric rings made of steel section, carried on suitable insulators.

The electric motor is controlled by a two-direction controller which always retains sufficient resistance in the circuit of the rotor to prevent damage from careless working.

2. Tractor with vertical adhesion surfaces.

(Fig. 11.)

This type of tractor, of which there is a large number, is based on a machine perfected by the Eastern Railway, and the above photograph of one of them coupled to a Paris, Lyons and Mediterranean table illustrates their general appearance and makes any detailed description unnecessary.

Bridge-tables.

(Figures 12 to 18 illustrate this type.)

As explained above, the Paris, Lyons and Mediterranean bridge-table, with the heaviest locomotive (182 t. [179.1 English tons]) of the system on it, can be turned easily by two men. This result has been obtained by using roller and ball bearings generally. The pivot is carried on ball bearings and the rollers on roller bearings.

Special arrangements have had to be made as mentioned below to keep these delicate parts free from any abnormal load which might affect their durability, to load the bearings of the pivot and the two bearings of the runners equally, and lastly to see the load is carried equally along the full length of the rollers.

In addition, every endeavour has been made to reduce the depth of the pit as much as possible, and with this object

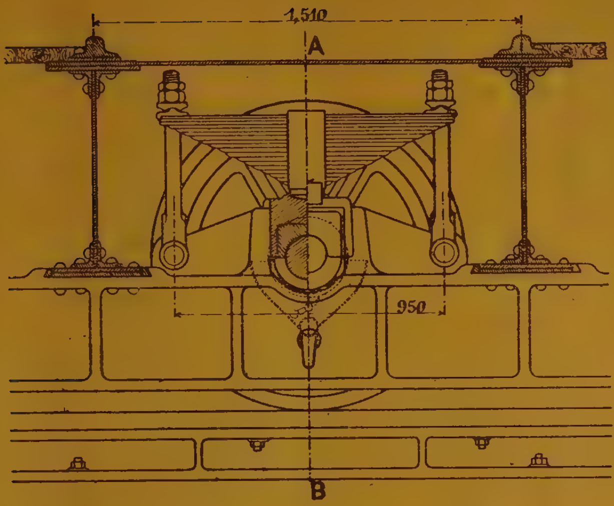


Fig. 3.

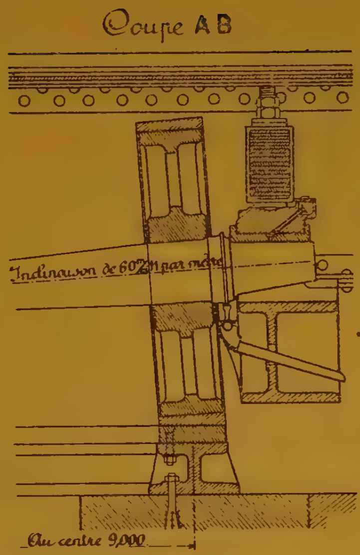


Fig. 4.

Explanation of French terms in figures 4 and 6 :

Au centre 9.000 = 9 m. (29 ft. 6 3/8 in.) to the centre.

nclinaison de 60 mm. par mètre = Slope of 6 per cent.

L de $\frac{100 \times 100}{12}$ = 3 15/16 × 3 15/16 × 15,32 angle.

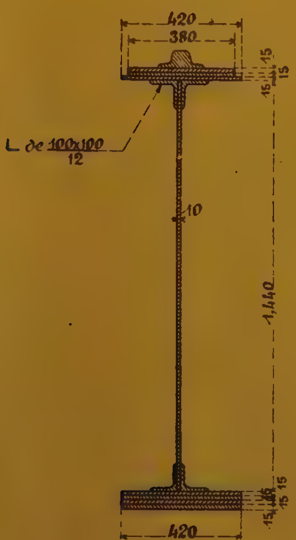


Fig. 6.

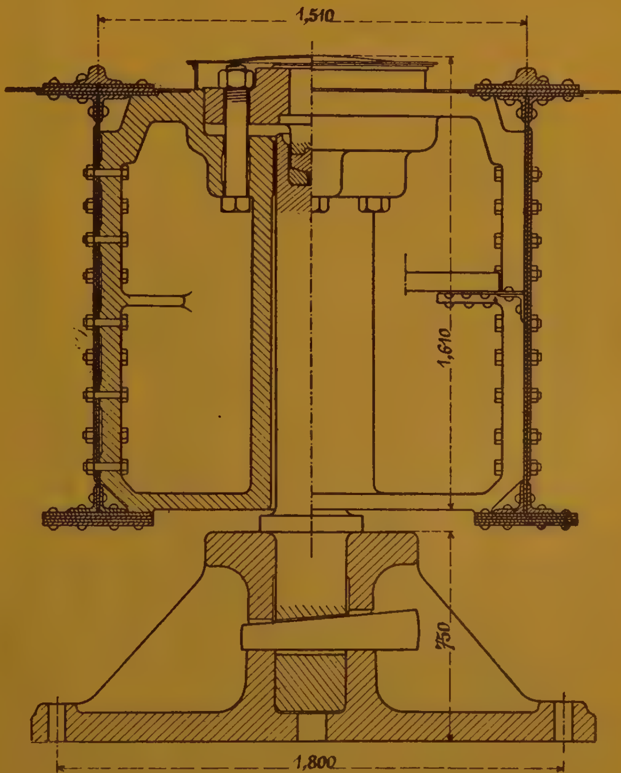


Fig. 7.

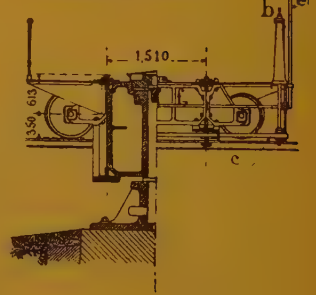
REFERENCE :

a. Locks.
b. Wheel operating locking gear.
c. Shafts operating locking gear.
d. Latches.
e. Turning lever on the table connected with the latch.
f. Shafts operating the latch.

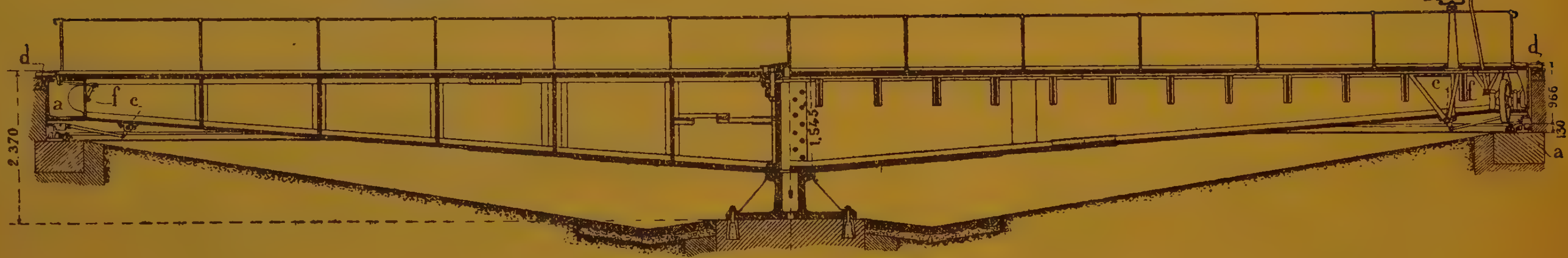
Explanation of French terms:

Rayon du chemin de roulement 11.195 = Radius of the circular track 11.195 m. (36 ft. 8 11/16 in.).

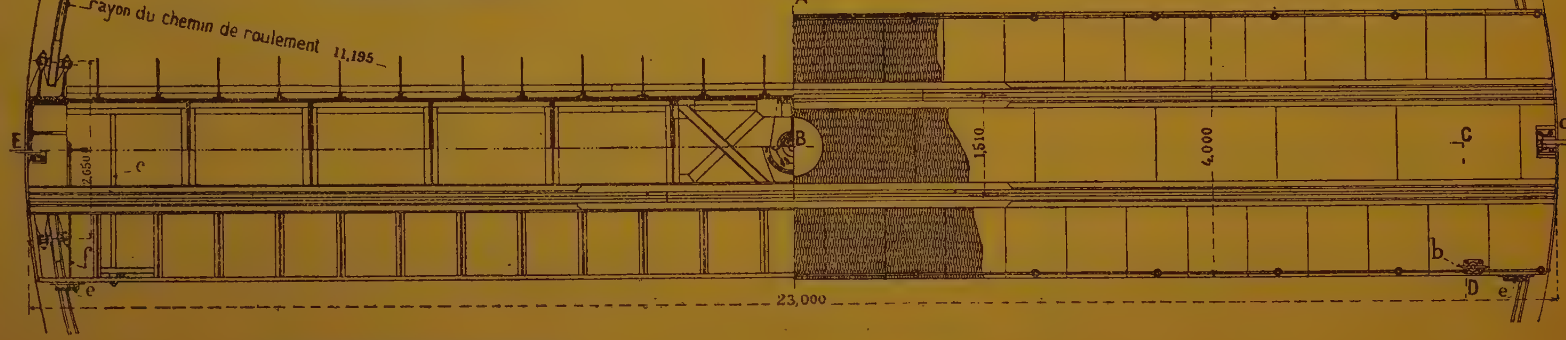
Section on ABCD.



Section on EB. **Half elevation.**



Horizontal half section. **Half plan.**



Half plan (platform plates removed).

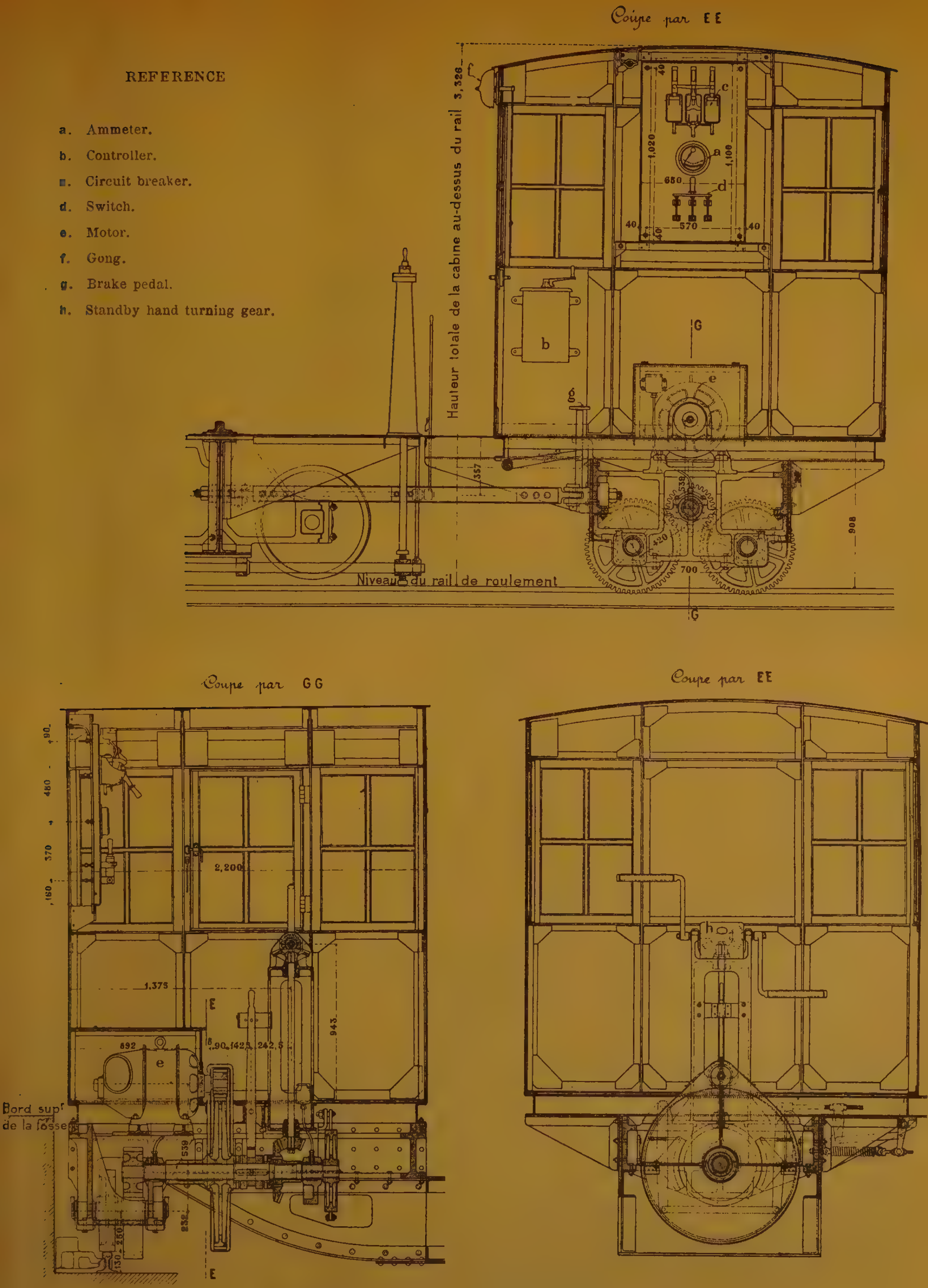


Fig. 8. — Horizontal adhesion tractor.

Explanation of French terms: Bord supr. de la fosse = Edge of the pit. — Coupe par EE = Section on EE. — Coupe par GG = Section on GG. — Hauteur totale, etc. : 3 326 = Overall height of cab above track level : 10 ft. 10 15/16 in. — Niveau du rail de roulement. = Circular track level.

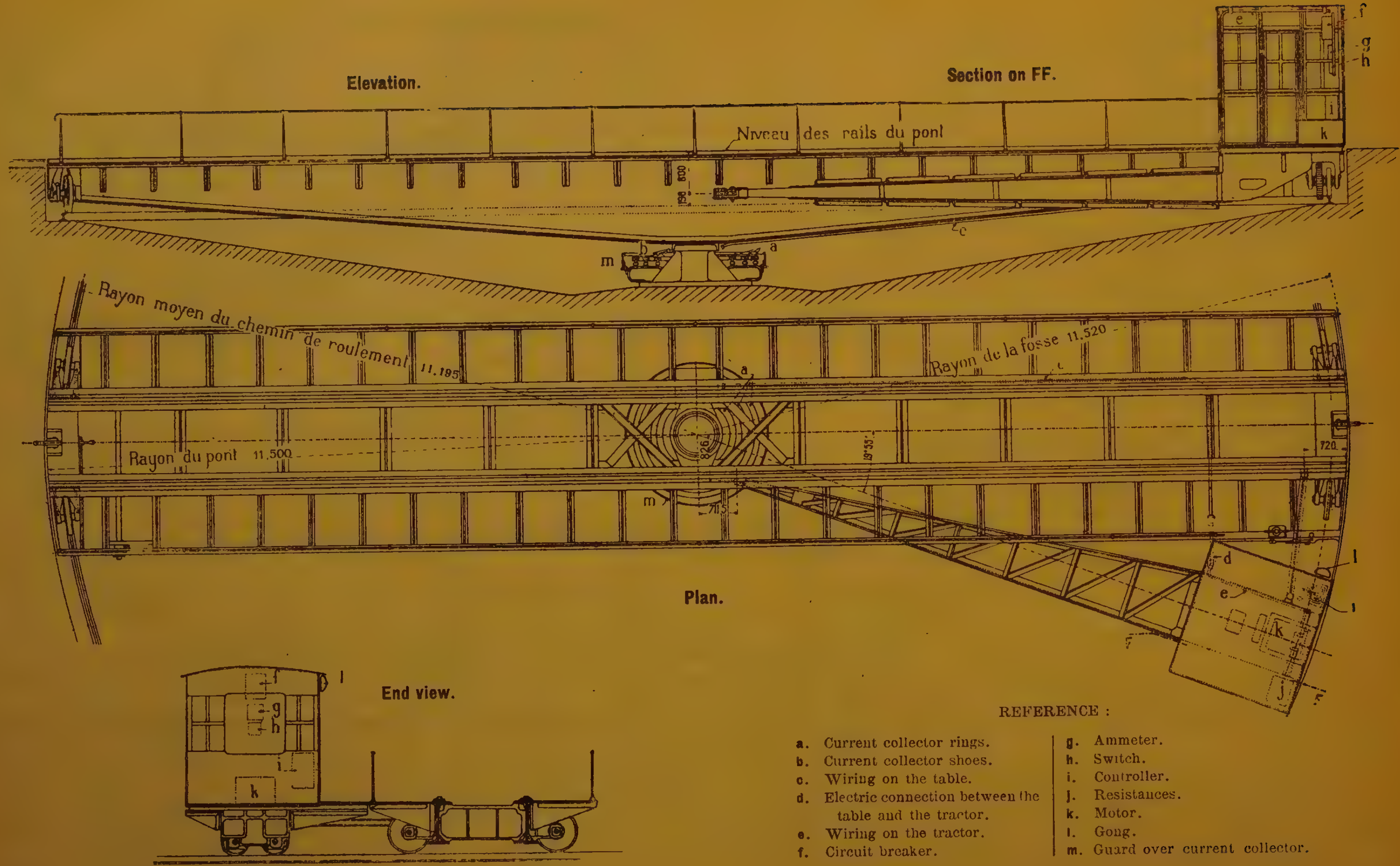


Fig. 9. — **23 m. (75 ft. 5 1/2 in.) open table coupled to its tractor.**

Explanation of French terms : Niveau des rails du pont = Level of rails on the table. — Rayon de la fosse 11.520 = Radius of the pit : 11.520 m. (37 ft. 9 1/2 in.) — Rayon du pont 11.500 = Radius of the table : 11.500 m. (37 ft. 8 3/4 in.). — Rayon moyen du chemin de roulement 11.195 = Mean radius of the circular track : 11.195 m. 36 ft. 8 11/16 in.).

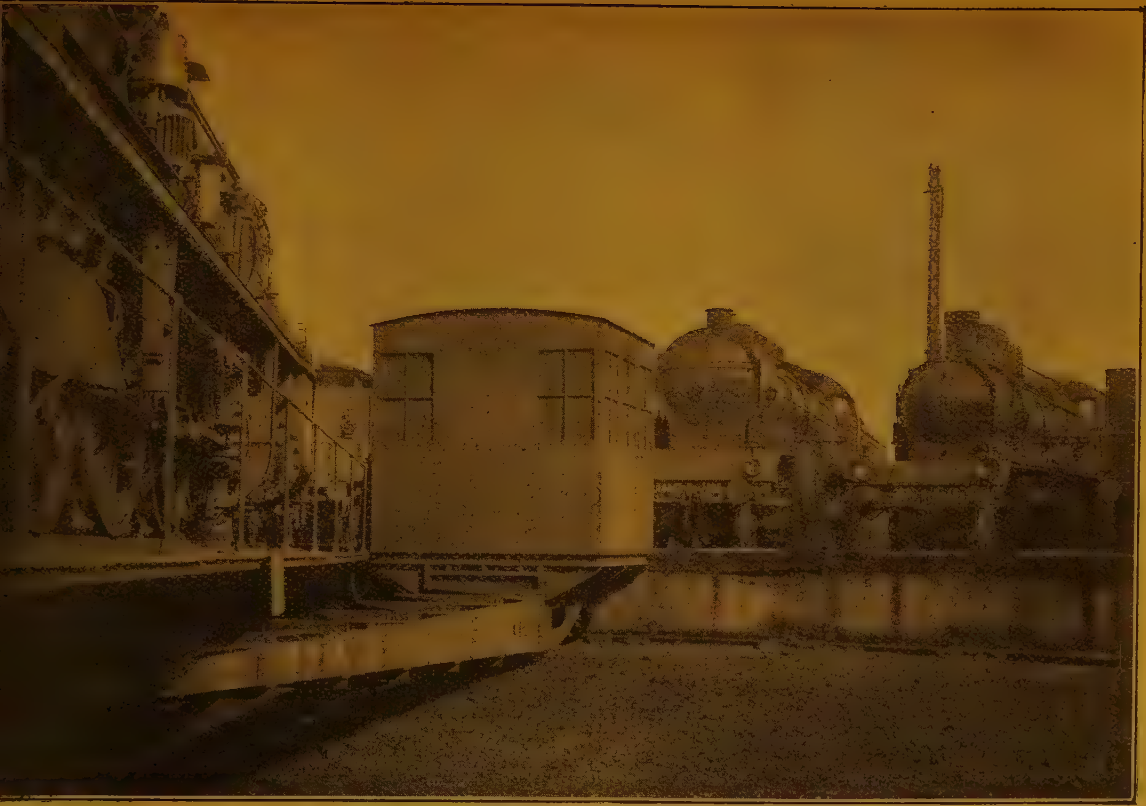


Fig. 10.

Fig. 11.

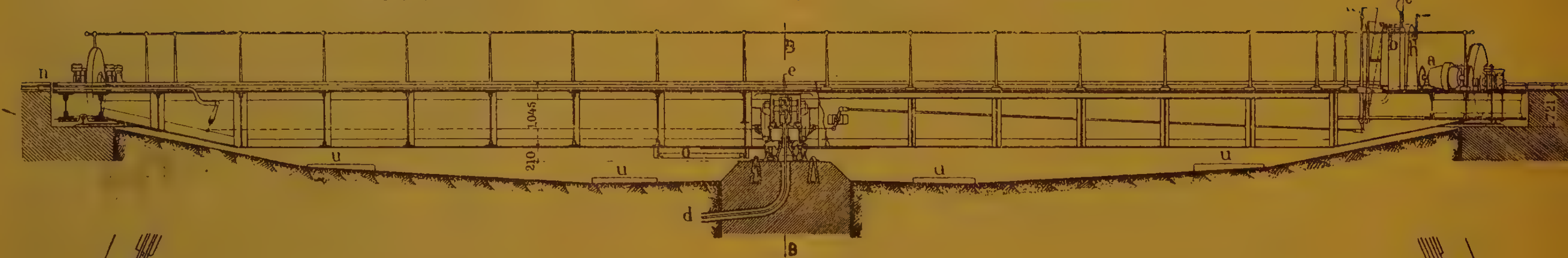


Fig. 12.

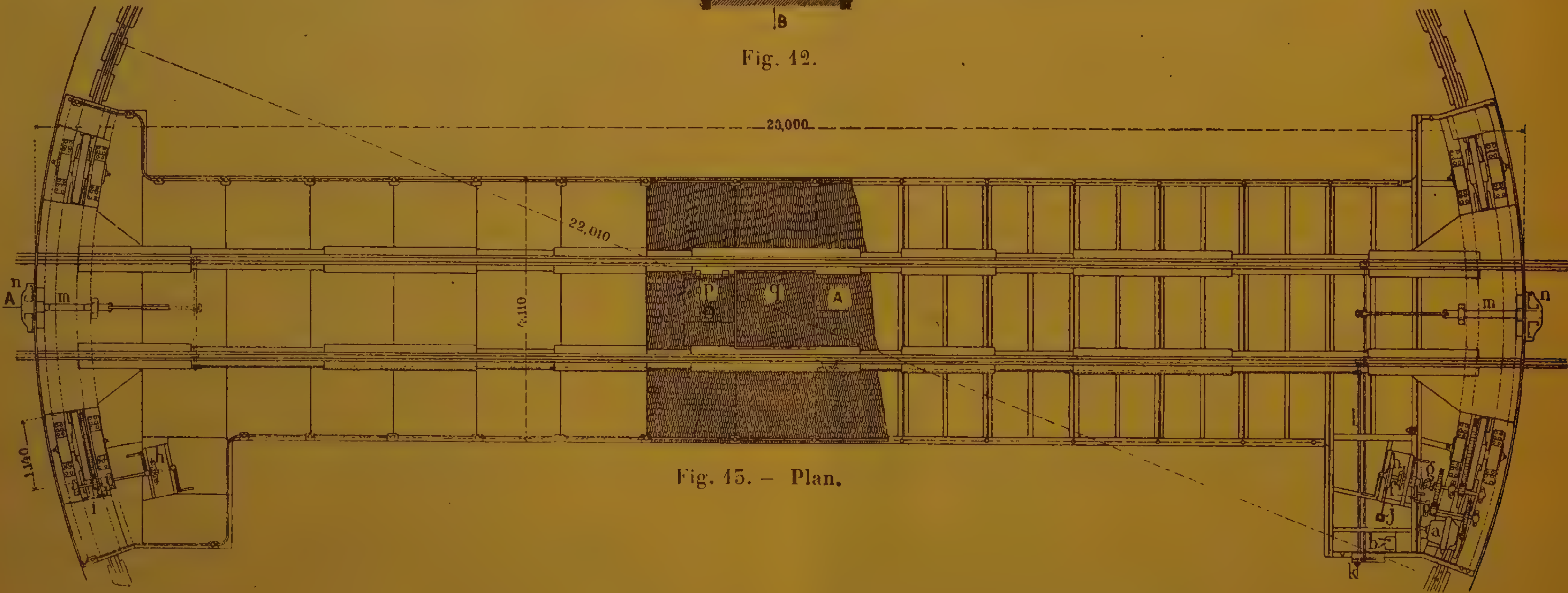
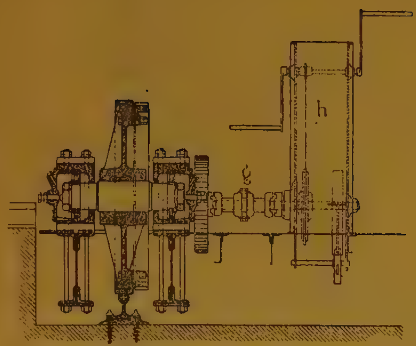


Fig. 13. – Plan.



Maximum pressure of a carrying wheel on the rail, 48 t. (47.2 English tons).

Fig. 14. — Section on CC.

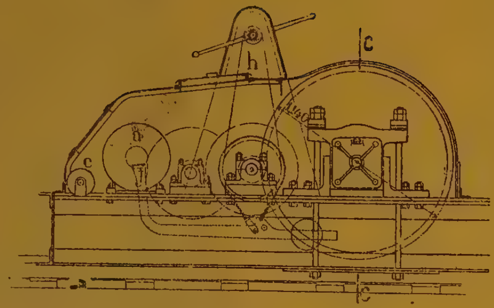
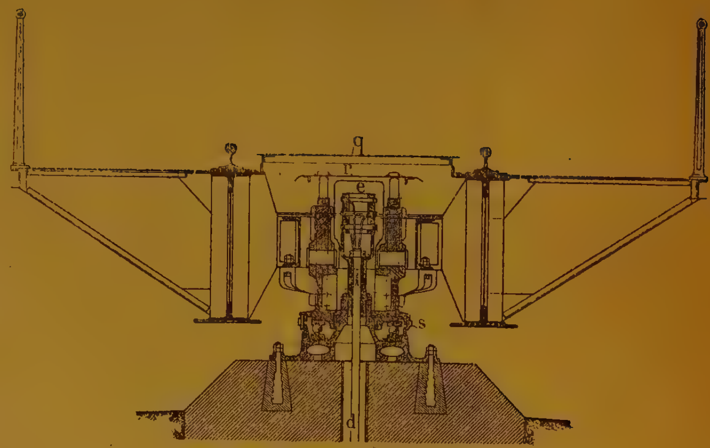


Fig. 15. — Outline (electric driving gear side).



Maximum pressure on the pivot foundation : 116 t. (114.2 English tons).

Fig. 16. — Section on BB.

Figs. 12 to 16. — 23 m. (75 ft. 5 1/2 in.) covered table electrically driven.

REFERENCE, FIGURES 12 to 16 :

a. Electric motor.
b. Controller.
c. Motor resistance.
d. Pipe for armoured cable.
e. Current collector rings.
f. Starting lever of motor and hand turning gear.
g. Clutch of motor and hand turning gear.
h. Hand turning gear.
i. Clutch lever of the hand turning gear (side opposite to the electric motor).
j. Band brake pedal.
k. Lever operating the locking gear.
l. Shafts operating locking gear.
m. Lock.
n. Box for the lock.
o. Staging for examining the pivot ball bearings.
p. Trap door giving access to the staging
q. Trap door for examining the current collector rings.
r. Cover plate over current collector.
s. Cover plate over ball bearings.
t. Gong.
u. Bearing for jacks for raising the table.

Fig. 17. — General view of 23 m. (75 ft. 5 1/2 in) bridge table.

Fig. 18. — 23 m. (75 ft. 5 1/2 in.) bridge table in use.

Fig. 19. — Comparison of depths of pit.

the depth of the girders was kept as small as practicable. Figure 19 gives a comparison of the section of the two pits, one for a bridge-table of 23 m. (75 ft. 5 1/2 in.), and the other for an open table of the same size.

The motor equipment was designed to stand rough use, however violent, and the current collector, which is placed inside the hollow pivot is completely protected against accidental contact, and has no exposed parts whilst being nevertheless readily got at for inspection and repair.

Structure. — The structure consists of two continuous girders built up of plate and angles, the section of the centre being shewn in figure 20. These girders carry the track. The rails are of the current pattern weighing 48 kgr. per metre (96.76 lb. per yard). The girders are joined together by eighteen stretchers built up of rolled sections. The two stretchers on each side of the pivot are much heavier than the others as they transfer the load to the pivot.

The main girders are connected at each end by large gusset plates with circular trimmers in plate and angles carried on two rollers with roller bearings.

The girders were designed on the supposition that the weight of the table itself was carried entirely by the rollers and that the rolling loads were distributed between the pivot and the rollers by the elastic deflection of the girders. It is very easy to get this distribution by properly adjusting the suspension gear during erection.

A platform of chequered plate is provided for walking about the bridge. This platform between the main girders is carried by these girders and their cross stays : the part outside them is supported on cantilever brackets built up of rolled sections attached to the webs of the girders. The platform has a hand rail along each side to prevent men from falling into the pit.

Ball bearing pivot.

(Figs. 12 to 16 and fig. 21.)

The pivot consists of :

A support *a* in cast steel carried on the foundation, with a 5 mm. (3/16 inch) thick lead sheet under it;

A S. K. F. ball thrust bearing;

A cap *c* in cast steel provided to distribute the load over the balls. This cap is centred in the support by a ring *d* in bronze to limit the destructive effects on the ball bearings of the blow due to an engine coming on to the plate, or to the violent application of the brakes when stopping an engine on it;

Two balancing levers *e* placed on the longitudinal centre line of the table, supported at the centre by the pivot cap *c*, and connected at their ends by four suspension bolts *f* to the middle stays of the main girders.

It will be appreciated that this arrangement assures the proper distribution of the load on the balls in spite of the longitudinal deflections of the girders during the movements when engines are moved.

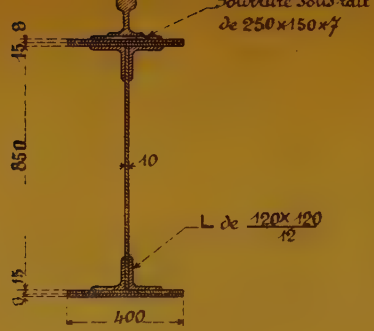


Fig 20.

Section through the centre pin of a bridge-table

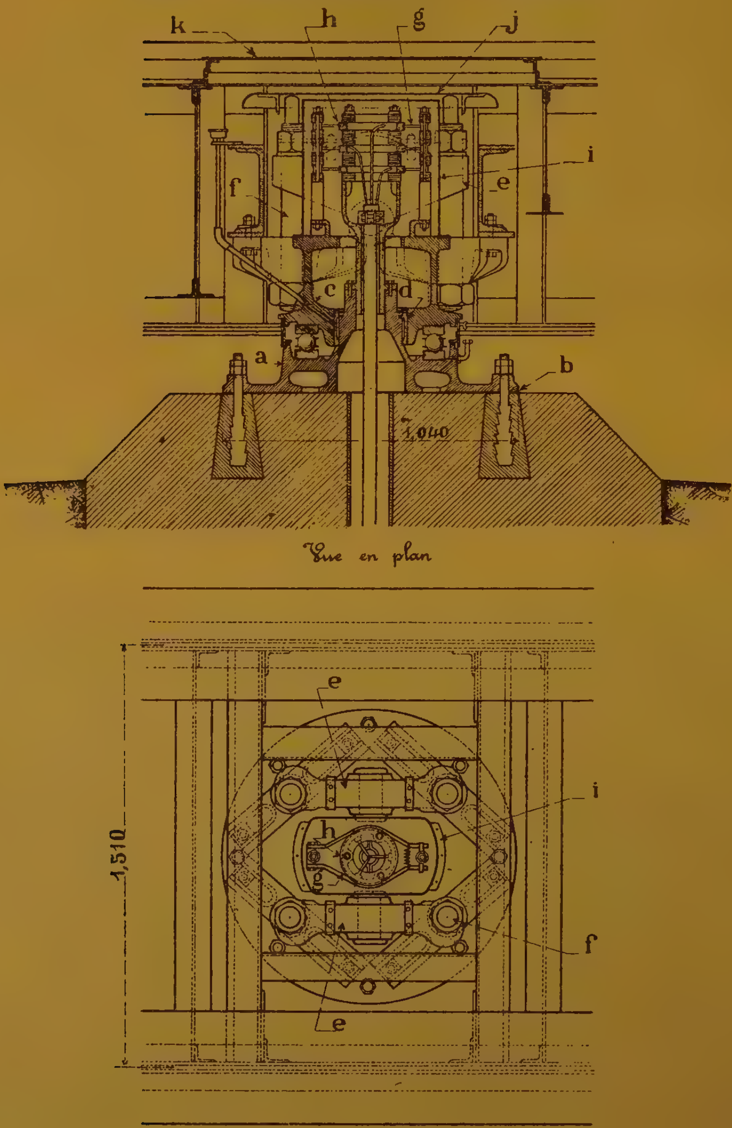


Fig. 21. — Pivot.

Explanation of French terms, figure 20

Fourrure sous rail = Packing plate. — L de $\frac{120 \times 120}{12}$ = 4 23/32-inch $\times$ 4 23/32-inch $\times$ 15/32-inch angle.

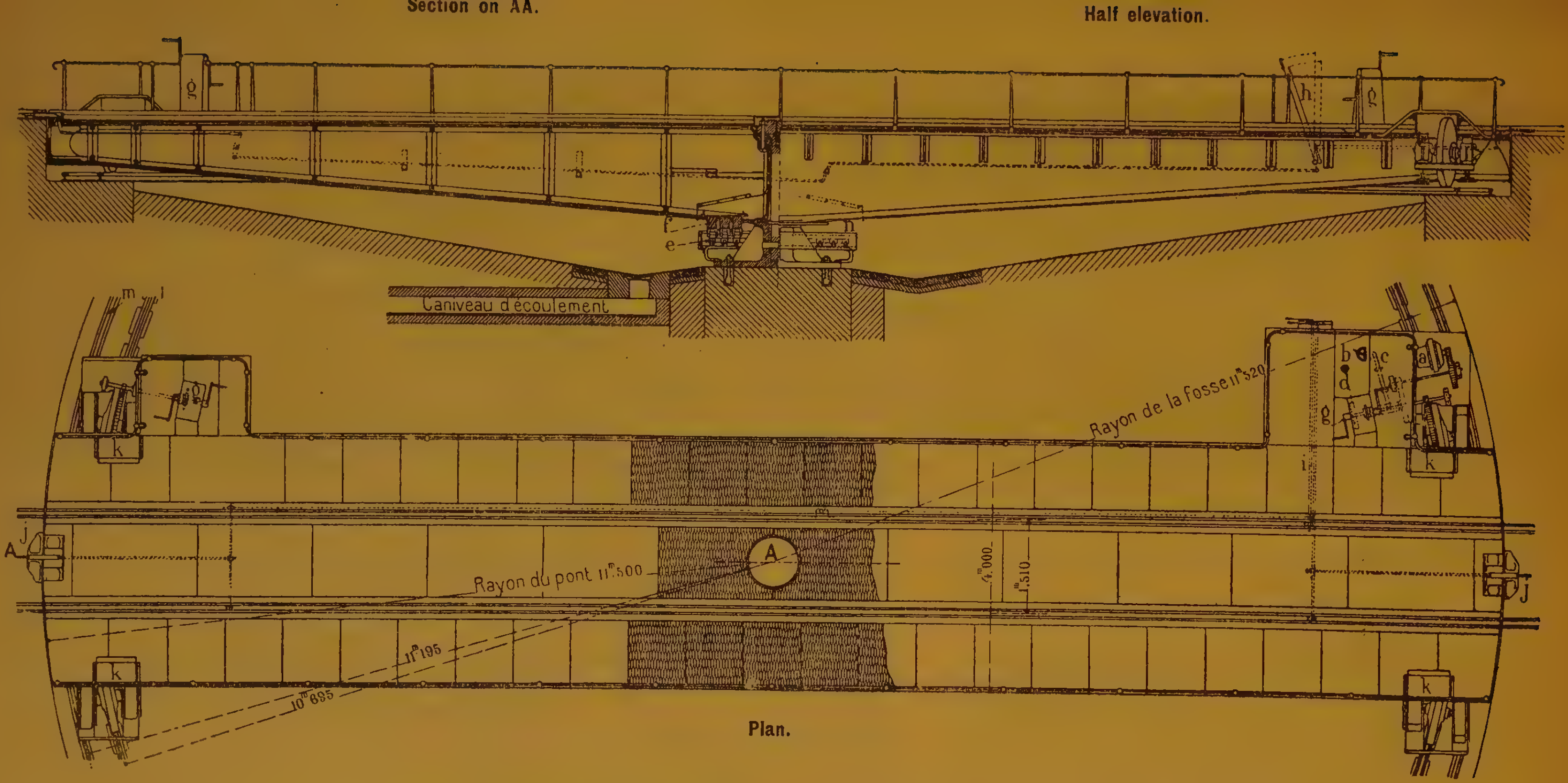


Fig. 22. — Bridge table 23 m. (75 ft. 5 1/2 in.) diameter electrically driven (old open table modernised)

REFERENCE :

- **a.** Electric motor
- **b.** Controller.
- **c.** Clutch lever for the motor or hand turning gear.
- **d.** Pedal band brake.
- **e.** Current collector rings.
- **f.** Current collector shoe brackets.
- **g.** Hand turning gear.
- **h.** Levers operating the locking gear.
- **i.** Shafts controlling the locking.
- **j.** Box for the bridge latch.
- **k.** Cover over the carrying wheels.
- **l** Circular track of altered turntable.
- **m.** Circular track of table before alterations (retained for possible use in emergency of an unaltered table).
- **n.** Covers over the current collector.

Explanation of French terms : Caniveau d'écoulement = Drain. – Rayon de la fosse 11 m. 520 = Radius of the pit : 37 ft. 9 1/2 in. = Rayon du pont 11 m. 500 = Radius of the table : 37 ft. 8 3/4 in.

By means of a quickly removeable cover, an inspector lying on a platform provided between the girders can examine the condition of the ball bearings both when the table is at rest and when being turned.

The current collector consists of three collectors *g* on three rings *h* placed between the balancing levers *e* and connected to the three conductors by an armoured cable coming up through the foundation. The whole collector gear is enclosed by the easily removed cover *i* which has an umbrella shaped plate *j* above it to prevent water getting into the collector for any reason whatever.

A trap *k* in the floor of the table above the pivot gives access to the suspension regulating gear as well as to the current collector.

As has been explained, the end trimmers of the table are supported by the rollers which have R. B. F. ball bearings. These bearings, of which there are eight, are all alike and are constructed as follows :

The interior ring is threaded on the end of the roller axle and held in place by a nut, the outer ring is fitted in the body of the bearing itself and held longitudinally by a plug held in place by four studs.

The load is transferred to the bearing by two pairs of bolts, the nuts of one pair acting on the bearings through a small bridge piece which distributes the load to the rollers independently of any unequal tightening up of the nuts of the two bolts.

The bearing itself can move vertically between two guides attached to the small end girder of the table. Two suitable extensions cast on the box fit in grooves machined in the guides and stop any movement of the bearing lengthwise or at right angles thereto horizontally, but allow the axle to take a slight inclination with regard to the horizontal plane without any ill effect.

Finally, centre stops on the box fronts take up any longitudinal thrust from defective setting of the runner wheels, or from shocks of oncoming engines, or of brake applications on engines stopped on the table.

The result of the whole arrangement is that the rollers are always loaded symmetrically about the centre of their length, are prevented from jamming through any slight inaccuracy in setting the carrying wheel pins horizontal, and finally are kept free from any longitudinal thrust.

Felt dust guards prevent dust from getting into the interior of the bearings.

Hand turning gear. — The bridge-tables can be worked either by hand or by motor as desired.

Motor drive (fig. 15, outline, turning gear side). — An electric three-phase motor with wound rotor, of about 5 H. P., drives one of the carrying wheels through suitable reduction gear, and turns the turntable with a locomotive on it in two minutes, including starting and stopping. A claw clutch enables the driving wheel to be driven either by the electric motor or by hand. A band brake, worked by a pedal acting in both directions, enables the table to be stopped accurately.

A two-direction controller controls the working of the motor. It is arranged so that there is always some resistance left in the rotor circuit which prevents any damage resulting from careless handling, such as a rough start or an attempt to change direction whilst in motion.

It is not essential therefore that the table should be worked by a specially trained employee. To avoid any doubt when working the table, the controller has been so arranged that the end of the table to which it is fixed moves in the same direction as that in which the crank is moved.

Hand operation (fig. 14, section on C.). — Two sets of hand turning gear enable

locomotives to be turned by hand if the current fails or the electric gear gets out of order.

One set is connected by the claw clutch mentioned above to the electric motor and turns the same carrying wheel as the latter. When worked by two men alone, the table can be turned in just under five minutes.

The other set is entirely separate from the first and turns one of the carrying wheels at the other end of the table on the same side of the table as the electric control gear : the gear reduction is less than for the former, and the table can be turned in two and three-quarter minutes with four men, on about three and a half minutes with three men.

The fitting of this second set with low reduction gear provides a very useful standby if the motor or current fail at places where high output is required and where there is no shortage of staff. The set with high gear reduction is reserved for use at places where there is no current and no staff other than the enginemen.

Locking (figs. 12 to 16). — The setting of the table track with the leading-in lines is assured by means of two locks sliding horizontally, placed at the ends of the table on the centre line of the track, which enter boxes arranged between the leading in rails by means of levers placed near the operating post. The locks have only 2 mm. (5/64 inch) side play in the boxes so that the table has to be stopped exactly in position by the brake before it can be locked. This avoids the damage that would occur if the play of the locks in the boxes was sufficient to allow the locks to be shot whilst the table was moving.

Circular track. — The track is made up of the ordinary type of rail as used on the table itself, bent as necessary, and carried on cast steel sole plates secured by coach screws to the foundation.

Owing to the ease with which the bridge-tables can be operated, the Paris, Lyons and Mediterranean Company has prepared designs for the conversion on the same lines of existing 23 m. (75 ft. 5 1/2 in.) open tables. (Figure 22 shews an open table altered in this way.)

The pivot with steel centre bearing plate has been kept unchanged, and the balancing wheels have been replaced by carrying wheels with roller bearings. The ends of the girders have been modified of course to stand the loads to be transmitted to the carrying wheels, and a new runway has been provided in consequence.

Turntables so fitted can be moved either by hand alone — or by an electric motor on the table — or by one or other of the tractors described previously. Pits prepared for the altered tables can also be used if necessary for ordinary tables without any alteration either to the table or to the pit.

[625 .13 (.73)]

Studies and methods adopted for ventilating the Holland vehicular tunnels.

Figs. 1 to 10, pp. 957 to 961.

(*Engineering News Record.*)

Progress on the vehicular tunnels being built under the Hudson River at New York has been recorded in « Engineering News-Record » as the work advanced. As the work draws to a close there remain two features of the work which have not been described — the ventilation studies and equipment, and the method of operation. This article deals with the ventilation. What is to be said on that subject is affected by the fact that an article on the ventilation of the Oakland Estuary tunnel, published in our issue of 10 March 1927, p. 392 (1)*, described work on a similar though much smaller structure whose ventilating system is like that of the Holland tunnels at New York and is based upon the studies and designs developed for the latter tunnels. Some of the general data given in that article which apply to both tunnels will not be repeated here.*

One of the major problems which faced the engineers of the New York and New Jersey tunnel commissions when they began to design the vehicular tunnels which now extend under the Hudson River from the neighborhood of Canal Street in Manhattan Island to 12th Street in Jersey City, was that of ventilation. Nowhere in the world had vehicular tunnels of similar length been built. Those of shorter lengths which have been in use in Europe for many years were devoted almost exclusively to horsedrawn vehicles prior to the time the studies at New York began and consequently required little or no artificial ventilation. The assurance that the majority of vehicles using the Hudson River tunnels would be motor-driven rendered the little knowledge of ventilating methods that could be obtained from European practice of no value.

Moreover, at the time the studies were begun there was but little information available as to the amount or character of gases given off by motor vehicles nor of the effect of various concentrations of those gases upon human beings. These conditions not only made an elaborate study of ventilation necessary, but also had a direct bearing upon the size and shape of the tunnel section to be adopted. On account of their magnitude, at least the general details of a ventilating system had to be worked out before contracts could be let for driving the underwater portions of the tunnels because the size and shape would depend, in large part, upon the space required for ventilating ducts.

Two general methods of artificial ventilation were available : 1. Longitudinal currents from end to end of the passageway of the tunnel or between vent shafts and 2. transverse ventilation from longitudinal ducts running parallel to the passageway. The former method, that of forcing currents of air through long sec-

(1) See *Bulletin of the Railway Congress*, July 1927 number, p. 601.

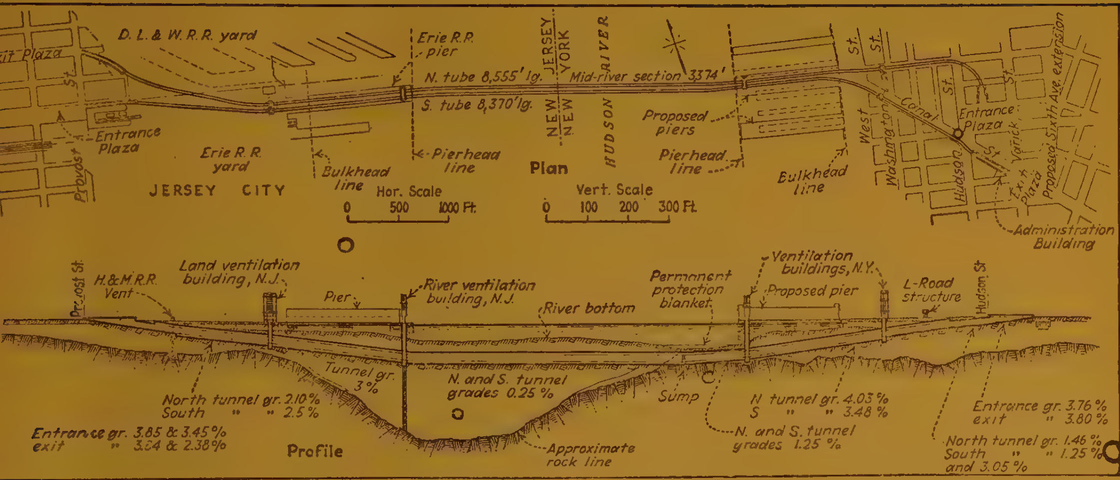


Fig. 1. — Plan and profile of the Holland tunnels.

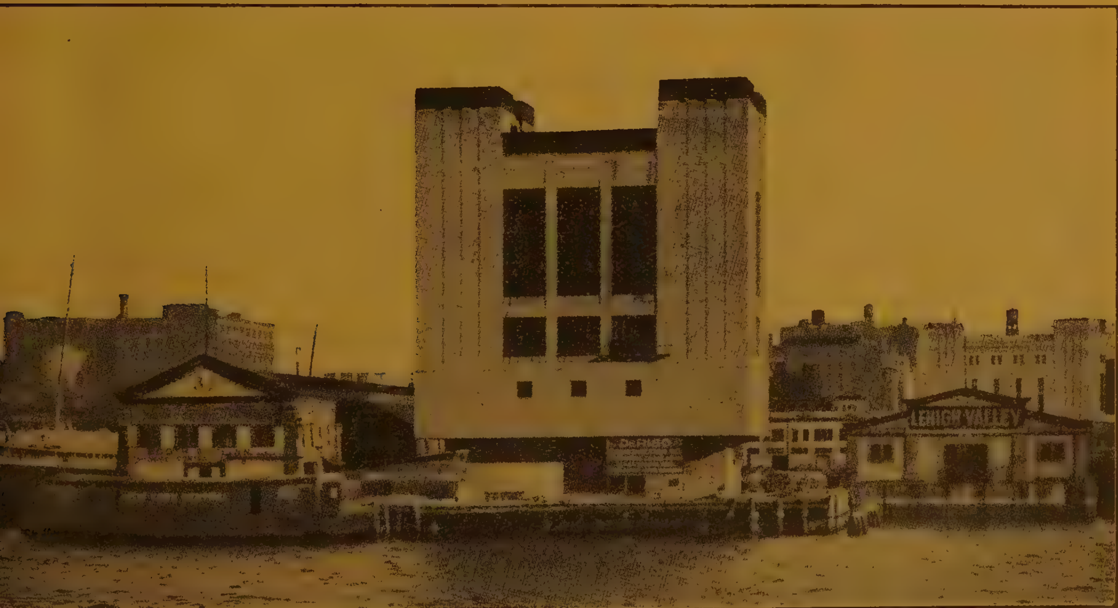


Fig. 2. — Pierhead ventilating building, New York.

Fresh air is taken in through the louvres in the sides of the building. Vitiated air is exhausted through the corner towers. The land ventilating building is in the right background.

tions of tunnel much as is done in the ventilation of railroad tunnels, was abandoned for reasons given in detail in the article on the Oakland Estuary tunnel referred to above, chiefly because of the impossibility of getting a uniform distribution of fresh air by that method and the danger in case of fire in the tunnel.

This left the transverse method as the most desirable, and as it required the use of large ducts for the delivery of fresh air and the removal of vitiated air from the tunnel, a circular section with a fresh air duct below the roadway and an exhaust duct above the roadway was decided upon as being the most economical for the underwater portions of the

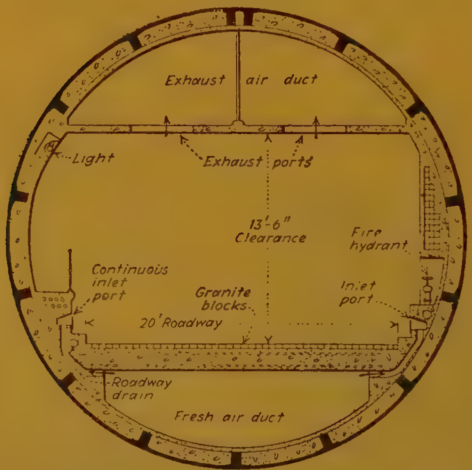


Fig. 3. — Cross-section of one tunnel.

tunnel (see fig. 3). The diameter of the cross-section was placed at 29 feet at that time. Subsequently, the diameter of the greater part of the tunnel was increased to 29 ft. 6 in. to give larger areas for the ventilating ducts. For the north tube at the New Jersey end where the location of the land shaft to suit conditions in the railway yards overhead made the outer section of that tube unusually long, the diameter was increased to 30 ft. 4 in. to give still larger ducts and to reduce the friction losses. That portion is the largest subaqueous tunnel in the world.

It was in 1919 that the general features were decided upon. Immediately thereafter a contract was entered into with the United States Bureau of Mines to make tests to determine the character and amount of poisonous gases given off by motor cars under various conditions of speed and grade, and of the physiological effects of such gases.

Tests on the composition of the gases were begun at the bureau's experiment station at Pittsburgh, Pa., in December, 1919, and completed in September 1920. While they were in progress other tests to determine the allowable air vitiation were undertaken at the Bureau of Mines station at Yale University. A report of these tests was given in *Engineering News-Record*, 7 April 1921, p. 602.

Exhaust gas tests. — The tests at Pittsburgh were made upon motor cars and trucks, chosen at random from vehicles in actual service, under both summer and winter conditions. They included all conditions of acceleration, of speeds up to 15 miles per hour, also idling, and on grades up to 3 1/2 %, approximately the maximum encountered in the tunnel. The tests showed that, although many gases were given off, carbon monoxide was the only asphyxial gas. The quantity of carbon monoxide given off varied so widely with the type of motor vehicle, carburetor adjustment and method of control that no average figure for all types and conditions of practical value can be given. However, the quantity of carbon monoxide in cubic feet per car per minute given off in the great majority of cases was between 0.57 and 2.80 at normal speeds. The amount of carbon monoxide produced per minute with engine idling was found to be smaller than for running conditions, indicating that when cars closed up in a blockade the air requirements will be no more than for normal operation.

Dilution tests. — The tests undertaken at Yale to determine the effect of automobile gases upon persons using the tunnel were directed toward establishing the amount of carbon monoxide that may be absorbed without harmful effect, the rate of absorption, and whether the susceptibility to monoxide poisoning varies in different individuals, also, whether other toxic gases were given off by gasoline engines. Tests were made upon persons in closed rooms with concentration of carbon monoxide gas of from 2 to 10 parts in 10 000, also upon a large number of persons in a closed room into which an automobile engine was exhausting. Test periods were 1 hour long, or twice the time required to pass through the tunnel at a rate 3 miles per hour.

The results of these tests showed that exhaust gases of gasoline engines contain no appreciable amount of poisonous substances other than carbon monoxide, although the smoke from improper combustion is irritating to the eyes and nauseating to some people. No variation in susceptibility was found. Mild concentrations of carbon monoxide have no noticeable or harmful effects; greater concentrations cause headache which disappears upon going out into fresh air. Concentrations up to 4 parts in 10 000 for 1 hour cause no ill effects, 6 parts are slightly noticeable, and 8 or 10 parts have a marked effect. Actual danger does not begin until much greater concentrations are reached. As a result of these tests a maximum concentration of 4 parts in 10 000 was selected as a criterion in design of the ventilating equipment.

Air requirements. — The estimated capacity of the 20-foot roadway in each tunnel is 1 900 vehicles per hour, but for purposes of estimating the air requirements this figure was raised to 2 113. For such maximum traffic the following amounts of fresh air were found to be required : 295 cubic feet per minute per foot of upgrade, 125 cubic feet for downgrade, and 225 cubic feet for level grade. These amounts gave a total of 1 919 982 cubic feet per minute for the north tube and 1 841 456 cubic feet for the south tube. A supply of this quantity of air will give an average of 42 changes per hour in the tubes.

Further tests. — While these tests on the character of exhaust gases and air requirements were in progress, a third series of experiments was being undertaken at the University of Illinois to determine the power required to move air through concrete ducts similar to those to be used in the vehicular tunnel, also the size and shape of exhaust and inlet ports, exhaust stacks and intake louvres.

Upon the completion of the three sets of experiments a final test was determined upon. It consisted in operating a tunnel in the experimental mine of the Bureau of Mines at Bruceton, Pa., in which the results of the previous experiments could be put into actual practice. A tunnel of cross-section about one-third that of the Holland Tunnel and 400 feet long was constructed. Automobiles were operated in it for 1-hour periods while tests upon the air conditions and the automobile operators were carried on. These tests confirmed earlier conclusions of the engineers on several points, including the very important one that the fresh air should be supplied close to the roadway level and the vitiated air drawn off from the top.

Ventilating equipment. — The location of the ventilating buildings and shafts is shown in figure 1. Two are at the pierhead line and two are inland, one between the two tunnels on Washington Street in New York City and the other north of the tunnels in the Erie Railroad yard in Jersey City.

Each land shaft ventilates four sections of tunnel, the adjoining portal sections of each tube, the whole intermediate section to the pierhead shaft where traffic

is on a downgrade and one-half of the parallel section where it is on an upgrade. The buildings over these shafts contain four independent sets of blower and exhaust fans. The pierhead shafts ventilate three sections of tunnel, one-half of each of the 3 400-foot river sections and one-half of the intermediate section where traffic is on the upgrade. In all there are 14 sets of blowers and 14 sets of exhaust fans. Dividing the upgrade sections of the tunnels into three parts gives added ventilation where the greatest amount of carbon monoxide is expected.

There are 28 ducts, 14 blower and 14 exhaust, connecting the various sections of the tunnels with the ventilating buildings. Each duct is equipped with three fans, two of which, when operated together, will supply the maximum quantity of air required. This gives standby equipment with a capacity of a little over half the required supply even if two fans of any duct should be disabled at the same time. There are 84 fans in all. Their capacities range from 81 000 to 227 000 cubic feet per minute and they operate at static pressures varying from 0.6 to 3.75 inches of water. This range in pressure and capacity is due to the great difference in length of tunnel ventilated by different sets, those at the outside of the pierhead shafts having 1 700 feet to serve while the inside fans have only 700 or 800 feet.

The fans are of the backward curved blade type, a type which can be operated in parallel. They are to be electrically driven by wound-rotor motors with resistance in the circuit to make it possible to run them at variable speeds. The combined capacities of the motors is approximately 6 000 H. P., two-thirds of which will be in operation at times of maximum load and one-third in reserve. Chain drives are to be used to make possible speed adjustments or changes in the motors as well as on account of the space limitations in the ventilating buildings.

A typical arrangement of fans in one of the ventilating buildings is shown in figure 6. The placing of the fans is varied to suit the local conditions in the individual buildings. Generally the exhaust ducts are at the corners of the buildings and supply ducts are in the central portion. Consequently the compartments containing the exhaust fans are located near the corners under the exhaust stacks leaving the central portions of the fan floors free for intake fans, and the central section of each outer wall for the air intakes. The intakes are made sufficiently large to give low velocities through the louvres.

The louvre blades are made of heavy wire glass to give light to the interior of the buildings as they take up most of the space otherwise available for windows. They are 8 inches wide, set at an angle of 45° and spaced 5 1/2 inches apart. Heavy bronze screens protect them and also serve to keep out birds.

The arrangement whereby fresh air is drawn in through louvres high up on the sides of the buildings and exhaust air is forced out through stacks which extend 20 feet above the roof insures a complete separation of fresh and vitiated air.

The vitiated air stacks are open at the top and are provided with drains at the bottom of the fans to carry off rain water. Snow will be blown out. Open tops were considered to be better than any form of hood which would increase the resistance to flow and deflect the vitiated air down toward the intakes.

The intake fans and their motors are situated in the open portions of the fan floors where they are accessible (fig. 7). The exhaust fans are, of necessity, inside of chambers at the top of the ducts. Their motors, however, are out on the main floor, the drive shafts being run in to the fans through close-fitting collars in the side plates of the duct (fig. 8). Access to the fans is provided through air locks equipped with airtight doors which can be opened against the unequal

pressure by wedge latches which force the doors open sufficiently to break the seal.

Each duct is equipped with a damper which may be closed when the fan is shut down so that air from the other fans will not be short-circuited through the idle fan. These dampers are motor operated from the control room and are equipped with limit switches.

Maintenance. — Every precaution has been taken to insure speedy repair work. No fan or motor has been so built that it cannot be taken out. The sides of the ducts which generally are of cast concrete or gunite on heavy reinforcing mesh, are made of bolted steel plates where they adjoin the exhaust fans so that the fans can be removed without having to stop to cut out a concrete wall. Fan casings are specially designed to facilitate removal of the fans. Trolley rails extend from a central hoist shaft to a point over each heavy piece of machinery. All machinery supports are arranged so that they can be disconnected from their concrete bases without having to cut out grouted beds.

All structural steel in the ventilating buildings except in the fans, access diaphragms and larger dampers is encased in concrete. The fans, diaphragms and dampers are to be heavily painted and are accessible for inspection. The exhaust port slides in the tunnel are of zinc and the exhaust ports are covered with bronze screens. Thin sides of ducts are made of gunite on heavy reinforcing mesh.

Power supply. — An unusually flexible system of power supply has been worked out based on the facts that all the motors are in groups of three, also that the maximum power equipments are less than the capacity of the minimum size power cables installed by the local companies. Three cables from the New York side and three from the New Jersey side are run to the bus bars in each ventilating building thus giving one motor in each set a separate cable connection to power supply on each side of the river. Interconnection at the bus bars makes it possible to cut in any or all motors on each cable. Thus connected, each motor may be supplied with power by six independent cables each capable of carrying the entire tunnel load; and, as there are at least two independent sources of power at each end of the tunnel, continuity of power supply is absolutely assured.

As the transformers are located in the ventilating buildings where smoke from an oil fire might be drawn into the ventilating system, air-cooled instead of oil-cooled transformers are used.

Fan control. — Each fan is provided with a control switch at the motor for emergency or repair use (see fig. 7); further local control is provided at the switchboard in each ventilating building, and complete operating control is provided at the main switchboard in the administration building where, by a system of signal lights, it will be possible, at all times, to tell what motors are in operation.

Distribution of air. — Air from the intake fans is forced down into the longitudinal duct under the roadway of the tunnel shown in figure 3, also in figure 4. From there it is fed through flues 10 to 15 feet apart into a continuous expansion chamber above the curb line at each side of the roadway, the flow of air into this chamber being controlled by adjustable slides over the flue openings. The outer side of the expansion chamber is a copper-steel plate which can be adjusted to give an opening of widths varying from 3/4 inch to 1 3/4 inches through which fresh air flows into the tunnel.

Vitiated air is drawn off through openings through the ceiling into the exhaust ducts. These openings are spaced 10 to 15 feet apart and are from 3 to 6 feet long.

Fig. 4. — Interior of North tunnel.

Above : The exhaust duct over the roadway.
Center : The roadway. Continuous fresh-air port shows as a black line midway between the curb and walk on the left; similarly on the right. Exhaust ports may be seen in the ceiling which had not been painted when this picture was taken.
Below : The fresh-air duct under the roadway. The small outlet ducts may be seen at both sides.

Fig. 5. — Bottom of blower duct.

Ducts from three fans combined to form one duct to the tunnel.

Fig. 7. — Typical blower fan.

One of the air inlet louvres beyond the fan. Fan control switch at left. The chain drive

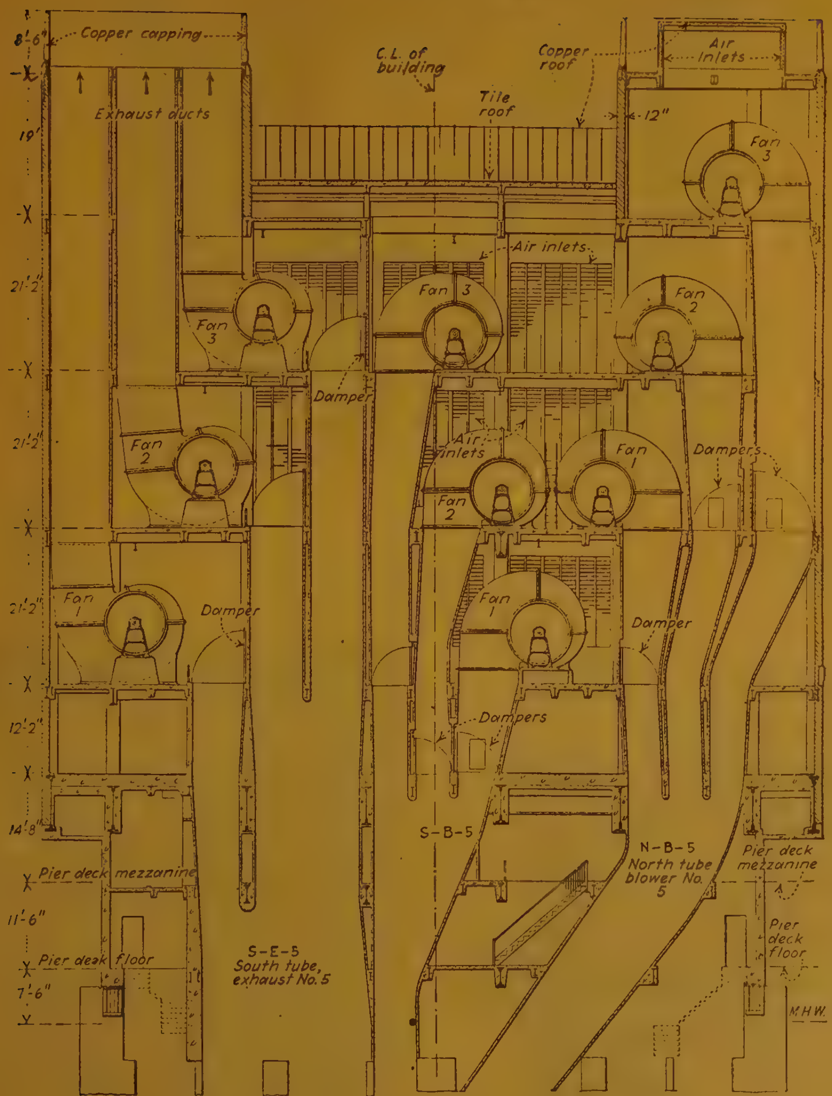


Fig. 6. — Typical vertical section through ventilating building.

They, also, are provided with slides by which the opening can be adjusted to meet the local requirements for air circulation.

By this arrangement of supply and exhaust ports, fresh air supplied to the roadway mixes with the warmer gases and rises to the ceiling where the exhaust ports are located.

There will be no longitudinal movement of air in the tunnels except that induced by the movement of vehicles,

Fig. 8. — Exhaust fan with chain casing open.

Motors of the exhaust fans are placed outside the fan room. The frame for the steel diaphragm closing off the room can be seen at the two sides and the foreground. The connection between the fan and the duct above was not made when picture was taken.

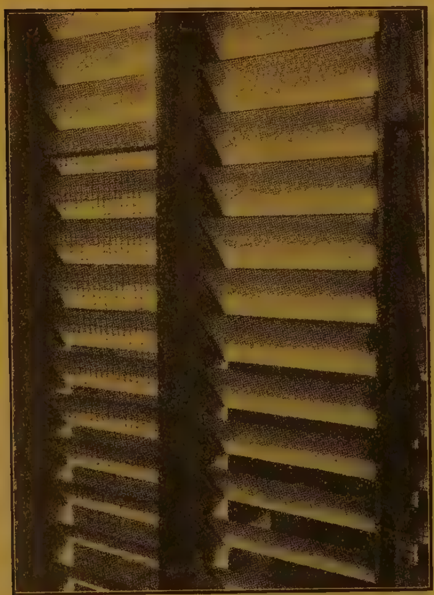


Fig. 9. — Details of the air intake louvres.

The louvre blades are of wire glass protected by bronze screens.

Fig. 10. — Interior of an air duct.

End of transition where duct has completed turning from under the roadway to a position at the side of the tunnel, the position occupied in the rectangular portions of the tunnel.

nor will there be any objectionable winds such as would be created by longitudinal ventilation. Tests made with smoke bombs showed that even large quantities of smoke will not spread far from the point of origin, but will rise quickly to the ceiling and be taken out. Similarly, in case of a fire the hot gases will rise to the ceiling where they will be drawn off. There will not be the same danger of spreading the fire from car to car that there would be with longitudinal ventilation.

Fire tests. — As part of the studies for the ventilating equipment numerous tests in relation to fire were made both in the test tunnel at Bruceton and at the laboratories of manufacturers of fire-fighting equipment. These tests included the burning of an automobile drenched with gasoline and with gasoline spilling from a hole in the tank on the car to determine how quickly such a fire could be put out with the hand extinguishers to be placed in the tunnel. As soon as the ventilating equipment of the tunnel is in operating condition and the fire-fighting apparatus is available a similar test will be made in the tunnel along with other tests for the final adjustment of the ventilating equipment.

Ventilation control. — As a check upon the air conditions in the tunnel, automatic carbon-monoxide recording devices are to be installed in each exhaust duct which will make a continuous analysis of the gases and record it graphically in the control room of the administration building in New York. There, by observing the chart, the operator can increase or decrease the fresh air supply as traffic conditions change in the tunnel.

Personnel. — The ventilation work has been carried on along with the other engineering work of the commissions, first under the general direction of the late Clifford M. Holland, then under his successor, the late Milton H. Freeman, and since March 1925, under the present chief engineer Ole Singstad. The ventilation plan and the program for the research work in connection therewith were developed under the direction of Ole Singstad, formerly engineer of designs. The ventilating equipment is being installed under the direction of Ralph Smillie, the present engineer of designs, A. C. Davis, mechanical engineer, and J. N. Dodd, electrical engineer. The tests at Pittsburgh were carried out under the direction of A. C. Fieldner, supervising chemist of the Bureau of Mines; those at Yale University under Yandell Henderson, consulting physiologist to the Bureau; and those at the University of Illinois under Prof. A. C. Willard, consultant on ventilation. L. B. Stillwell is electrical consultant.

Construction of the ventilating building is being carried out under contract with the De Riso Construction Co. and the fan and motors are being installed by the B. F. Sturtevant Co. and the General Electric Co. respectively.

[656 .253 (.42)]

Four-aspect colour light signals and power signalling in practice, [1]

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Figs. 1 to 10, pp. 968 to 988.

Cannon Street and Charing Cross. Four-aspect colour light signals and all-electric power signalling.

The traffic working between Cannon Street, Charing Cross and London Bridge had been carried on under an intensive signalling system for several years with favourable results, but the introduction of electric traction on the area of the Eastern section called for a still more intensive system or something more efficient and effective to enable the increased traffic it was proposed to run to be got through safely, at the same time, with increased efficiency and economy.

It was first proposed to provide all-electric power signalling system with three-position semaphore arm signalling and electric working of points in a similar way to the plant at Victoria, Eastern section. Eventually, it was thought better to instal an all-electric power signalling plant, the signals to be on the four-aspect colour light system and electric motor worked points, the lock and block working over the whole area to be changed from SYX lock and block to either automatic or controlled automatic. To effect this, the whole of the rails in the area has been divided into insulated or track circuited sections, and an illuminated diagram has been placed in each signal box to enable the signalman to see the condition of the various sections of the line under his control, *i. e.*, whether occupied or « clear » and to see the movements of the traffic over the sections which he controls. This, with the electric interlocking, the track circuits, and the locking on the levers in the frame, is relied upon for the block working as is done on other parts of the railway.

The new lay-out at Cannon Street provides routes from all platform roads to both the down local and through lines and from the up local and through lines to all platform roads, except in the extreme case from the up local to number 1 platform road. The consequence is that the quantity of signal and point mechanical interlocking is very large, considerably larger than for any signal frame with the same number of levers yet made, due to the very large number of routes there are into and out of the station. (See fig. 1.)

The four-aspect colour light signal system has been installed over the whole area Charing Cross and Cannon Street to Borough Market junction and Holborn to Elephant and Castle. It is the first installation of the kind in the world. Three colours, red, yellow and green only, are used, the four aspects are arranged as follows :

Four-aspect running signals.

Green	All right.	Proceed.
Two yellow (double yellow)	Warning.	Be prepared to find next signal at caution.
One yellow (single yellow).	Caution.	Be prepared to find next signal at danger.
Red	Danger.	Stop.

[1] Paper read on 18 May 1927, before the Institution of Railway Signal Engineers, London.

Three-aspect running signals.

Green	Proceed.	Platform road clear to buffer stops.
One yellow	Caution.	Platform road partially occupied by vehicles.
Red.	Danger.	Stop.

Two-aspect shunt signals.

Green	Proceed as far as line is clear, or to the next signal only.	
Red.	Danger.	Stop.

Thus only three colours are used, and each aspect is definite : green, always indicating clear; yellow, warning or caution, red, stop. It is arranged that before a driver arrives at a red light or stop aspect, he must pass a double yellow or warning signal, and afterwards a single yellow or caution signal; he therefore has two cautionary signals instead of one under the semaphore system. The meanings of the light signals are definite, whereas the distant semaphore signal, in practice, may mean, when it is in the horizontal or danger position, that 1. the three signals ahead are « *on* », 2. only one out of three is « *off* », or 3. two are « *off* » and one « *on* ». Further, the distant signal has to be placed full braking distance away from the home signal under the worst conditions. Thus when working a fast and heavy goods train the driver would have only this one signal, whereas with the four-aspect colour light system he is told the condition of the road ahead. If a green light is exhibited, he knows that the road is clear and he can travel as fast as he is able or up to the speed restriction there may be for the line he is travelling over; also that three sections ahead, at least, are clear. The double yellow aspect is placed full braking distance from the signal he has to stop at and is really the aspect for a driver travelling at 75 miles per hour, who seeing this aspect would begin to get his train under control and when he arrives at the single yellow aspect he is again cautioned to be prepared to stop at the next signal. The single yellow aspect may be said to be for the driver running at from 30 to 40 miles per hour, such as the motormen of electric trains. A red light definitely means stop.

This system avoids the necessity for a driver to pass the danger, stop signal or a red light under any circumstances, as he had to under the semaphore system, also it is unnecessary to provide repeater signals at places where the driver cannot see the signal he is approaching, quickly enough to act upon it, as the aspects he has passed tell him the state of the road ahead. In any case, as it was decided that the driver should not pass a red light, it is impossible to use repeaters, as if an aspect were red, the repeater would also shew red, and it would be necessary for the driver to pass that red light. It has therefore been arranged in the very few cases it may be required that an auxiliary signal shall be used. This takes the form of a brilliantly illuminated white cross on a black background over a three-aspect colour light signal, green, single yellow, and double yellow. No red light is used. The normal aspect is the white St. George's cross on a black background. If the signal aspect is red, the auxiliary shews single yellow. If the signal aspect is single yellow the auxiliary is double yellow. If the signal is double yellow or green the auxiliary will be green, but there are no auxiliary signals in the area as it was found they were not required.

It has been arranged that where a driver has to pass a shunt signal applying to his road, the shunt signal shall precede the running signal, so that the shunt signal aspect shall be green as the driver passes it.

The signalling scheme provides for the

maximum number of parallel moves and all the possible shunt moves are signalled, so that traffic movements can be made quickly and without a shunter. The whole of the shunt signals are free of the track circuit control, except for the back locking.

The block sections vary in length from 200 to 500 yards; an endeavour has been made to provide overlaps of 200 yards, but is has not been possible to do this in every case in a very great measure due to the dense traffic during the rush hours and the complicated junctions and in many cases the overlaps are shorter than this. In one case the overlap is 13 yards, but there a speed restriction of 25 miles per hour has been imposed by the Ministry of Transport.

It has also been arranged that when a train is going from the up line at Borough Market junction to the branch line at Metropolitan junction a yellow aspect shall be exhibited in the Borough Market junction home signal, and a red aspect at the Metropolitan junction up home to branch signal until the engine reaches the commencement of a track circuit 193 yards away from the signal, when it will change from red to yellow, double yellow, or green, according to the state of the road ahead of the signal.

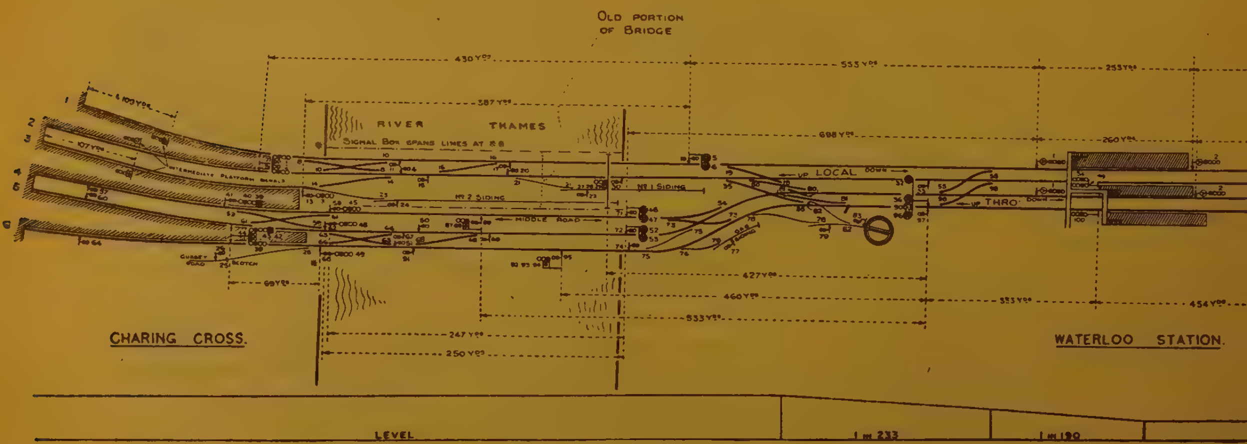
Shunting movements are governed by two aspects: red, danger, stop; and green, proceed as far as the line is clear or the next signal only.

In view of the fact that the driver gets two warnings (one warning and one caution) it is a question whether overlaps are necessary when the four-aspect colour light system is used.

If the driver is aware that overlaps beyond the stopping points are provided, he is not so likely to use such care, as if he knew that the stop signal had to be rigidly obeyed. To a driver the exact spot where the overlap ends is unknown, or at least indefinite, whereas the stop signal is a definite and distinct indication that he must stop there and he will get in the habit of obeying the signal.

Further, overlaps tend to lengthen the section, and thus decrease the capacity of the line which is of great importance at busy stations, especially during the rush hours.

The diameter of the lenses for running signals is 8 inches, intermediate signals 4 inches and 2 inches in the case of shunt



signals, but this, not proving very satisfactory, is being modified by having a 4-inch etched sheet glass in front of a coloured 4-inch lens to give the necessary spread of the aspect. Figure 2 gives details of all the aspects in use.

The electric supply for power signalling.

Two sources of electric supply for signalling purposes have been provided.

1. Alternating current electry supply, 220 volts at 75 cycles for supplying energy to the electric lamps in the signal aspects and for the electric locks in the electric controlling apparatus.

2. Direct current electric supply, 110-140 volts, for operating points.

The reason for a dual supply is that it is necessary to maintain the supply continuously and always in railway power signalling work. If one alternating current supply is provided, in case of emergency, such as the main, or sub-stations breaking down, there is no stand-by, and then all the signalling apparatus including illuminated diagram, signal aspects and controls would be put out of use and

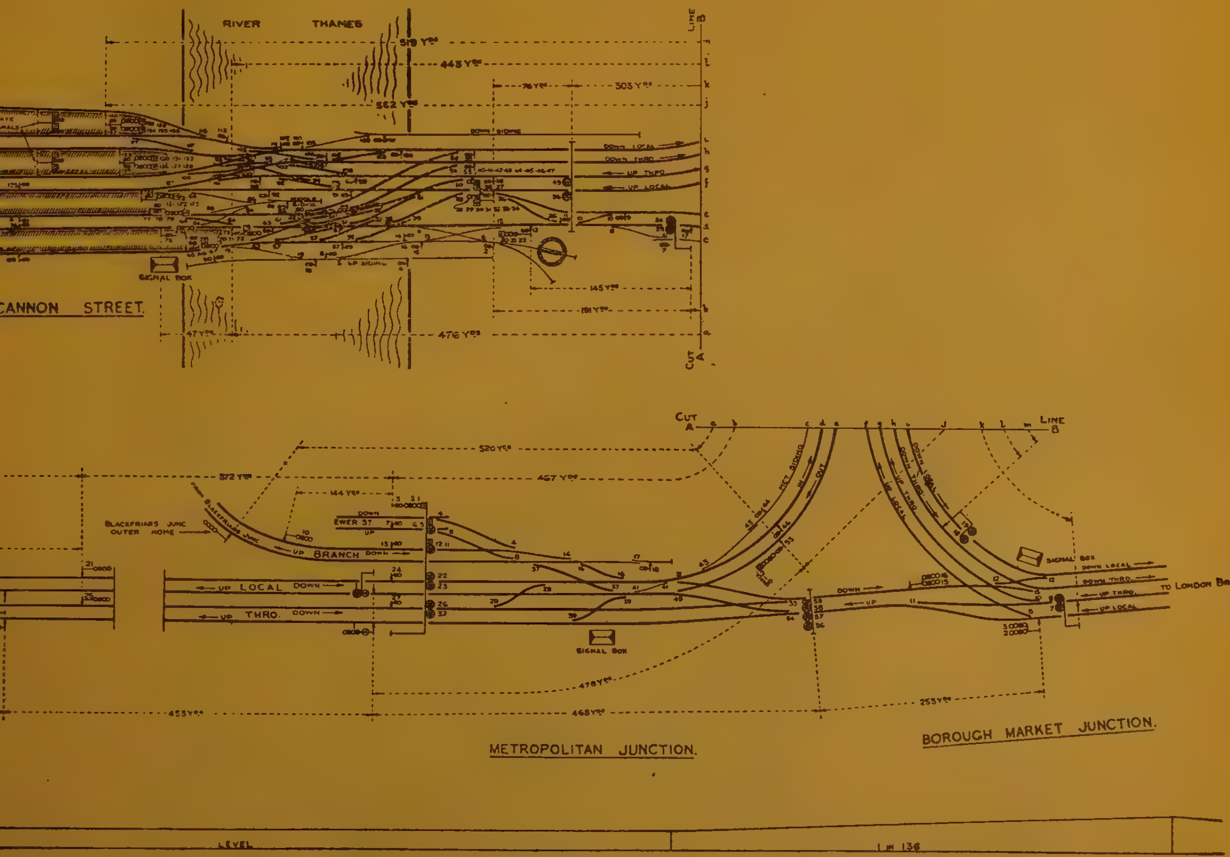


Fig. 2. — Colour light signals.

TABLE I.

Particulars of electric energy supply.

27 June 1926 to 2 September 1926.

STATION.	Alternating current. Energy. Total kilowatt-hours.	Alternating current. Energy. Average weekly kilowatt-hours.	Primary. Volts.	Primary. Amperes measured.	Secondary. Volts.	Secondary. Amperes.	Energy. Total kilowatt-hours.	Energy. Average weekly kilowatt-hours.	Charging. Volts.	Charging. Amperes.	Discharging. Volts.	Discharging. Amperes.	*Remarks.*
Cannon Street	13 312	1 365	220	45.0	110	90	994	105	650	32	140	10.0	When points operated.
Charing Cross	13 484	1 386	220	42.0	110	86	978	100	650	32	140	10.0	
Metropolitan Junction . .	7 089	728	220	220	110	34.2 } 47.0	...	...	...	...	...	...	
Borough Market Junction.	...	...	...	...	110	12.8 }	...	...	...	...	...	...	

the point movements would too, had it been arranged to work them by the alternating current supply. The point movements are therefore worked by direct current, so that in case of such an emergency the points could be operated from the signal box and the safety of the mechanical interlocking maintained.

The energy for the alternating current supply is taken from the Deptford supply station of the London Electric Supply Co., to the Company's main sub-station at Lewisham, and there transformed by a rotary converter to single phase alternating current, 75 cycles, at a pressure of 3 300 volts, and transmitted to three kiosks : 1. at Cannon Street; 2. at Charing Cross; 3. Metropolitan junction, where it is again transformed from 3 300 volts to 220 volts and thence taken to the signal boxes where it is transformed to 110 volts by means of static transformers. Mains are run throughout the local areas to the various points where a supply of 110 volts is required.

The total alternating current taken at each of the signal boxes is shewn in table I.

The direct current supply.

Two batteries of 70 accumulator cells (70 each), at Charing Cross and two at Cannon Street have been installed to give the direct current 110-150 direct current supply. They are of 260-ampere-hour capacity, their charging rate is 32 amperes, and the maximum discharging rate is 24 amperes, but of course this can be varied over a great margin and is generally about 12 amperes. It is somewhat dangerous to discharge the batteries at too high a rate and short circuits of every description should be avoided as far as possible.

The electrical energy for charging the accumulator batteries, is taken direct from traction power conductor at 650 volts to the switchboard, then through the usual and various switches to the

motor of the motor-generator set, which revolves at 1 400 revolutions per minute. The direct supply voltage varies considerably, according to the density of the traction load, and the 12-H. P. motor is specified to work at from 560 to 650 volts and 17 amperes. The generator gives 7.68 kilowatts at a voltage, varying according to the traction current density from 140 to 192 volts. It is necessary to provide substantial and long fuses and overload and no-load cut-outs and to see that the main switch has a good quick break action, otherwise an arc is liable to be started and maintained. A current of about 32 amperes passes to the battery on charge at a voltage of from 110 to 150 volts. The discharge for working the points is from 10 to 20 amperes, but only while the points are being operated.

The second accumulator battery is supplying current at from 125 to 140 volts and the discharge current varies, but may be taken as 12 amperes. The capacities of the batteries are sufficient when fully charged to supply current for three days. There are no direct current mains over the areas, as the wires for working the points and route indicators are run direct from the control contacts in the signal frame in the signal box to the points themselves in a 5 or 7-wire cable. This materially reduces the risk of any shorts, or cross-connection contacts between wires.

The wires in the 5-wire cable are as follows for single-ended points :

1. 1/14 coloured green normal movement.
2. 1/14 coloured white : reverse movement.
3. 1/14 coloured black : return.
4. 1/16 coloured blue : normal indication.
5. 1/16 coloured red : reverse indication.

Seven wires for double-ended points :

6. 1/14 coloured yellow : normal for second point machine.
7. 1/14 coloured pink : reverse for second point machine.

Ground signals : 3-core cable 1/16 standard wire gauge :

1. 1/16 coloured red : red aspect.
2. 1/16 coloured green : green aspect.
3. 1/16 coloured white : return aspect.

Operation of light signals.

At stations or signal box control areas the light signals are semi-automatic. The signalman has the ultimate control of the signal aspects, insomuch that when the signal lever is in the normal position back in the frame, the aspect of that signal displayed is red, and the aspects of the two signals in rear would be, provided the sections were clear, single yellow and double yellow respectively, but when the signalman reverses the signal lever to the « off » position the signal is then entirely automatic and the aspect exhibited depends upon the state of the road, and the aspects displayed ahead. If the section ahead is clear and the next signal ahead is red, then the aspect will be yellow. If two sections ahead are clear and the next aspect single yellow, then the aspect will show double yellow, and if three sections ahead are clear and the next signal ahead is double yellow or green, then the aspect exhibited will be green.

The running signal levers in the frame are electrically locked or free according to whether the controlling track circuits and point detector relays indicate that 1. the road ahead is clear, and 2. the point tongues are correctly set against the stock rail. Unless these conditions are fulfilled, the lever is locked and the signalman cannot get his lever from « on » to « off ». Further, if he did get the lever to the « off » position, the aspect would remain red until the track circuited section ahead was clear and the points set correctly and completely to their proper position, that is close to the stock rail.

Having pulled the lever to the « off » position, the aspect of the signal operated by the lever will assume the aspect according to the condition of the road ahead, similarly the aspects in the signals behind will exhibit the sequence of aspects according to the system. If the road is clear ahead and behind, then as the lever is pulled « off » the aspect will change from red to single yellow, double yellow, or green, according to whether one, two or three sections are clear. The aspects of the signals behind will similarly change until the correct sequence of aspects are exhibited. Thus directly the signalman takes his control off the signal, it becomes an automatically worked signal depending entirely on the state of the road and lay of points. Having set the route and pulled the signal lever to the « off » position, the signalman can replace the lever to the check lock position and when the red aspect is displayed completely, the movement of the lever to the normal or « on » position can be completed if he so desires, before the train reaches the first track circuit in the approach locking control; after this his lever is back-locked until the train passes a certain point ahead of the signal. Instead of using an ordinary treadle, the function of the treadle is performed by two track circuit relays being de-energized at the same time by the train itself. It is, however, arranged that the signalman can always replace his lever to the back check lock position and thus cause the aspect of the signal, whichever was showing, to change to red immediately, but the back lock will not be released until the train has passed the spot, the pre-arranged distance ahead of the signal and not till the aspect has changed to red.

If from any cause the track circuited section ahead of any signal displaying green, double yellow or single yellow aspects becomes occupied, the signal aspect whatever it may be at the time, will immediately and automatically go to red.

The train having passed the signal into the track circuited section ahead, the aspect will immediately automatically and irrespective of the signalman change to red, and the signalman is made aware of the fact that the train has passed into the track circuited section ahead by means of the illuminated signal diagram. The lever should be replaced to the check lock position and when the aspect has gone to the red condition, the check lock is released and the lever can be completely replaced to normal. In the ordinary way, if the signalman did not replace his signal lever, the signal aspect would work automatically, irrespective of the signalman, according to the state of the road, but it is important and necessary that the signalman should know for certain when every train passes his box, and the apparatus is so arranged that the signalman must replace his signal lever after the passing of each train. If he does not replace his lever to normal then the aspect in his home signal remains at red and of course the drivers will not pass it. This is effected in the following way :

1. As the train enters on the first approach control track circuited section, the signal lever is back locked.

2. The train entering the first track circuited section ahead of the signal, drops a stick relay which has the effect of disconnecting the electric lock control circuit and consequently back locks the signal lever until the train passes over the track circuit, a predetermined distance ahead.

3. The train passed over the spot and back lock is free, but the signal aspect remains red as the control circuit is disconnected.

4. The lever replaced resets the stick relay and everything is now normal, and the signalman, if the section ahead is clear, can again pull the signal lever to the « off » position.

One special feature of this signalling

installation is that no « key » or other release apparatus is provided. In case the signalman has set up a wrong road, or any fault arises, the electric lock has to be released by the lineman.

Operation of points.

An electric point movement is placed in the six-foot, near to and by the side of each pair of points, and connected to the tongues through the stretcher rod as described later, to move the points from normal to reverse or vice-versa.

The point levers normally lie back in the frame. When it is necessary to reverse a pair of points, provided the track circuited section is clear, the signalman pulls the point lever from the normal to the over position as far as the check lock position. Had there been any vehicle standing on the points, the lever would have been track locked, and the lever could not have been moved.

The power current circuit for working the points from normal to reverse is now completed and a direct current at 110 to 130 volts passes from the bus bar, through the contacts on the lever to the field magnet coil A of the motor and through the armature in series; the armature revolves until the points have completed the movement, including the facing point lock. The check lock circuit is then closed and an alternating current at 110 volts, 75 cycles, passes to the electric lock on the frame, releasing the check lock and the indication behind the lever shows the letter R. The signalman then completes the stroke of the lever to the reverse position. The circuit diagram of the point connections is given in figures 3 and 4.

A similar set of operations would be necessary in replacing the lever from reverse to normal position in the frame, but the indication on the check lock being released would be N, showing the point tongues were in the correct normal position. The mechanical locking in the frame would be operative to prevent a conflicting movement during the time the lever was in the check lock position, and until the lever had completed its stroke to normal or reverse, as the case may be.

It is necessary that the lever movement be made deliberately to the check lock position, and not « jiggered » backward and forward, or an electric arc is likely to be set up between the contact springs in the signal frame, and the aspect exhibited in the signal itself may vary and the point tongues not take up the movement desired. In this connection it must be understood that the apparatus and machines have been designed for a purpose under given and practical conditions and it is, within limits, imperative that the whole installation should be operated in accordance with the methods laid down for its working.

There is a small over run of the motor after the movements of points have been completed, but this is minimized by keeping the working voltage as low as possible.

Electric point machines

The electric point machines used at Cannon Street is the Westinghouse Brake & Saxby « M » type and contains a 1 H. P. electric motor.

The field magnets are double wound, the coils being arranged in series with the armature. The resistance of the field magnet coils is 2.6 ohm per coil and the armature resistance approximately 0.75 ohm. The number of turns on the field magnet coils is 000.

The energy for working the points is taken from the bus bar in the signal box through the lever contacts, figure 3, direct to the point motor, the armature of which revolves :

	Single pair of points.	*Double ended points.*
To unlock points. . . .	13 times.	23 times.
To complete stroke. . .	50 —	91 —
To complete cut-off. . .	64 —	112 —
To cut off clutch. . . .	67 —	117 —

One motor.

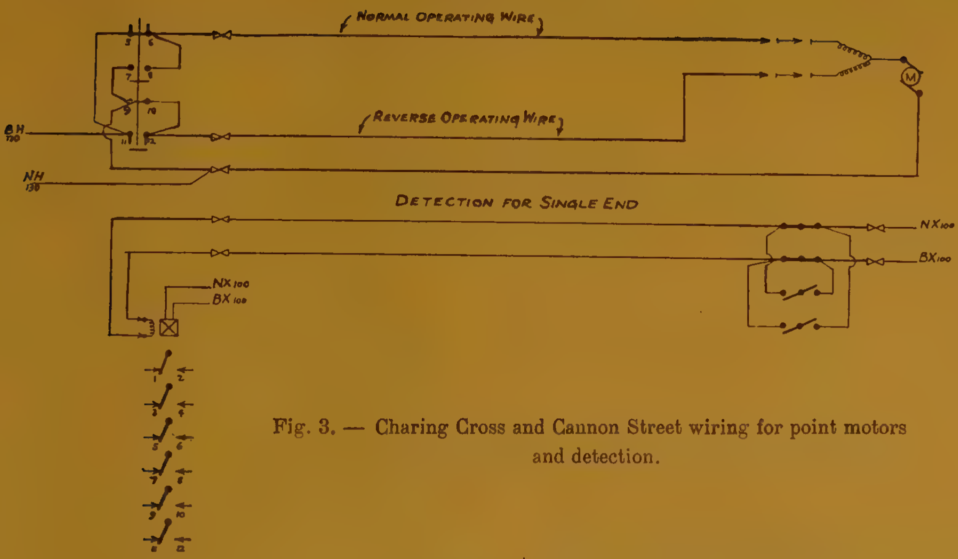


Fig. 3. — Charing Cross and Cannon Street wiring for point motors and detection.

Two motors.

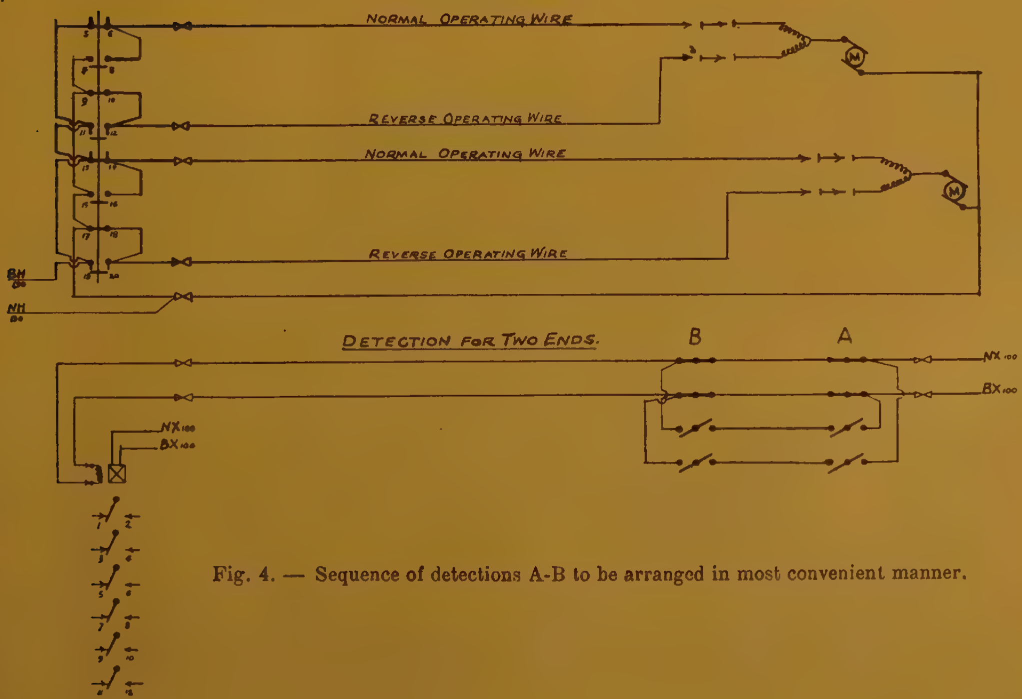


Fig. 4. — Sequence of detections A-B to be arranged in most convenient manner.

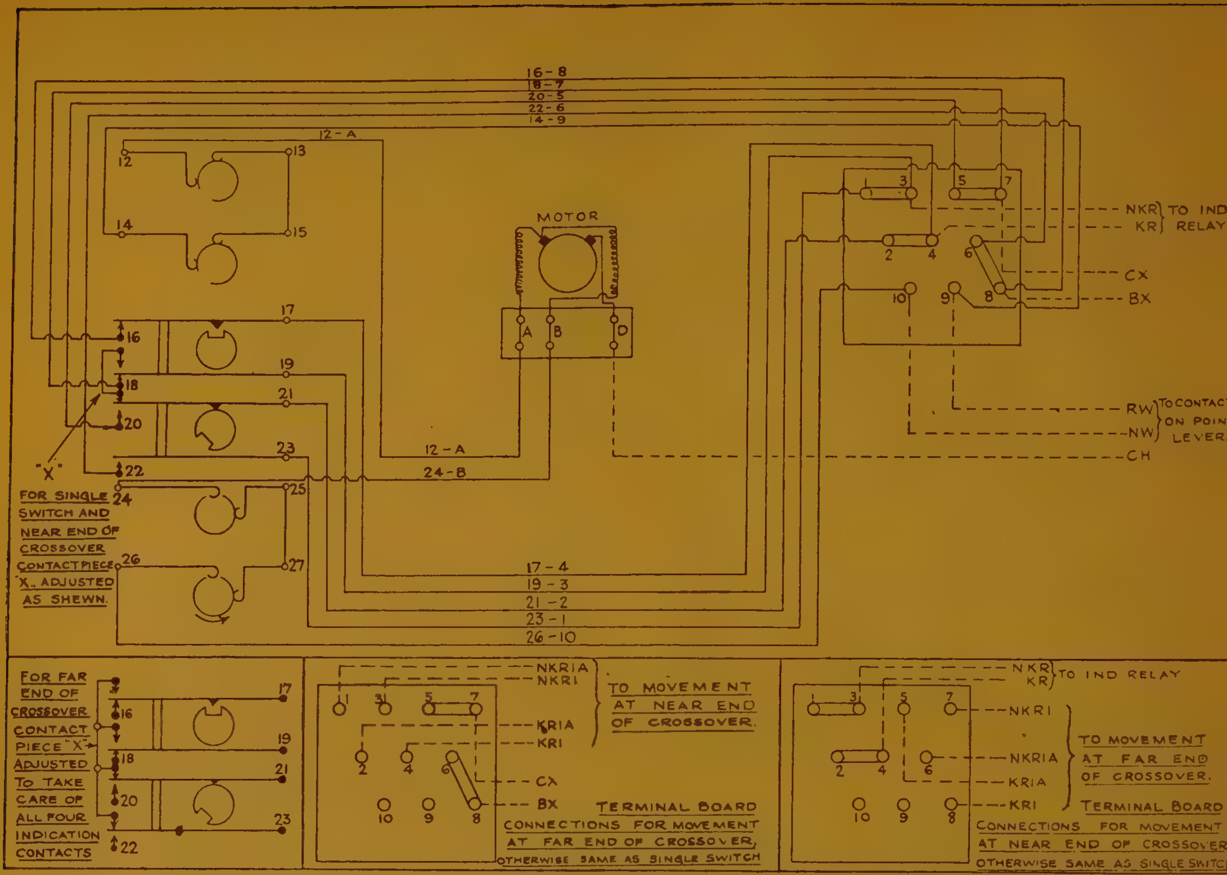
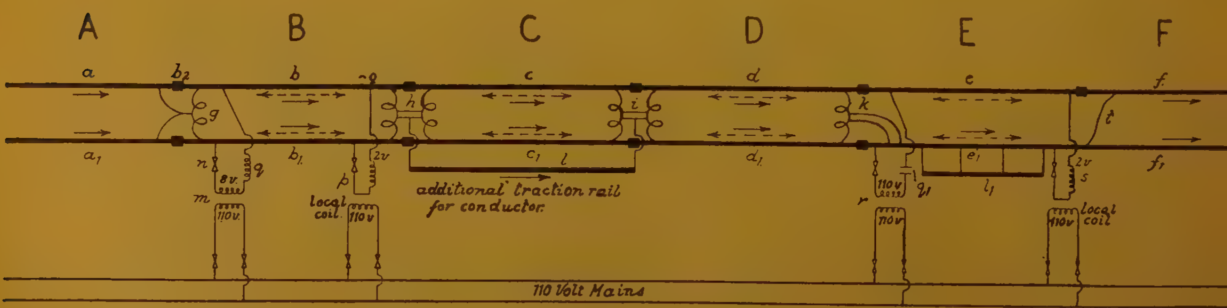


Fig. 5. — Wiring diagram for style « M » point machine with direct current motor and alternating current indication, detection contacts in machine.

Wiring as shewn is for movement on switch with right hand point normally closed. When left hand point is normally closed, interchange exter[nal] leads to 9 and 10 and reverse indication controller cams in accordance with page 9 of instruction pamphlet.



Alternating current.

Direct current.

Fig. 7. — Typical circuit diagram shewing the simultaneous use of the running rails for alternating current track circuits and the return for traction electric current.

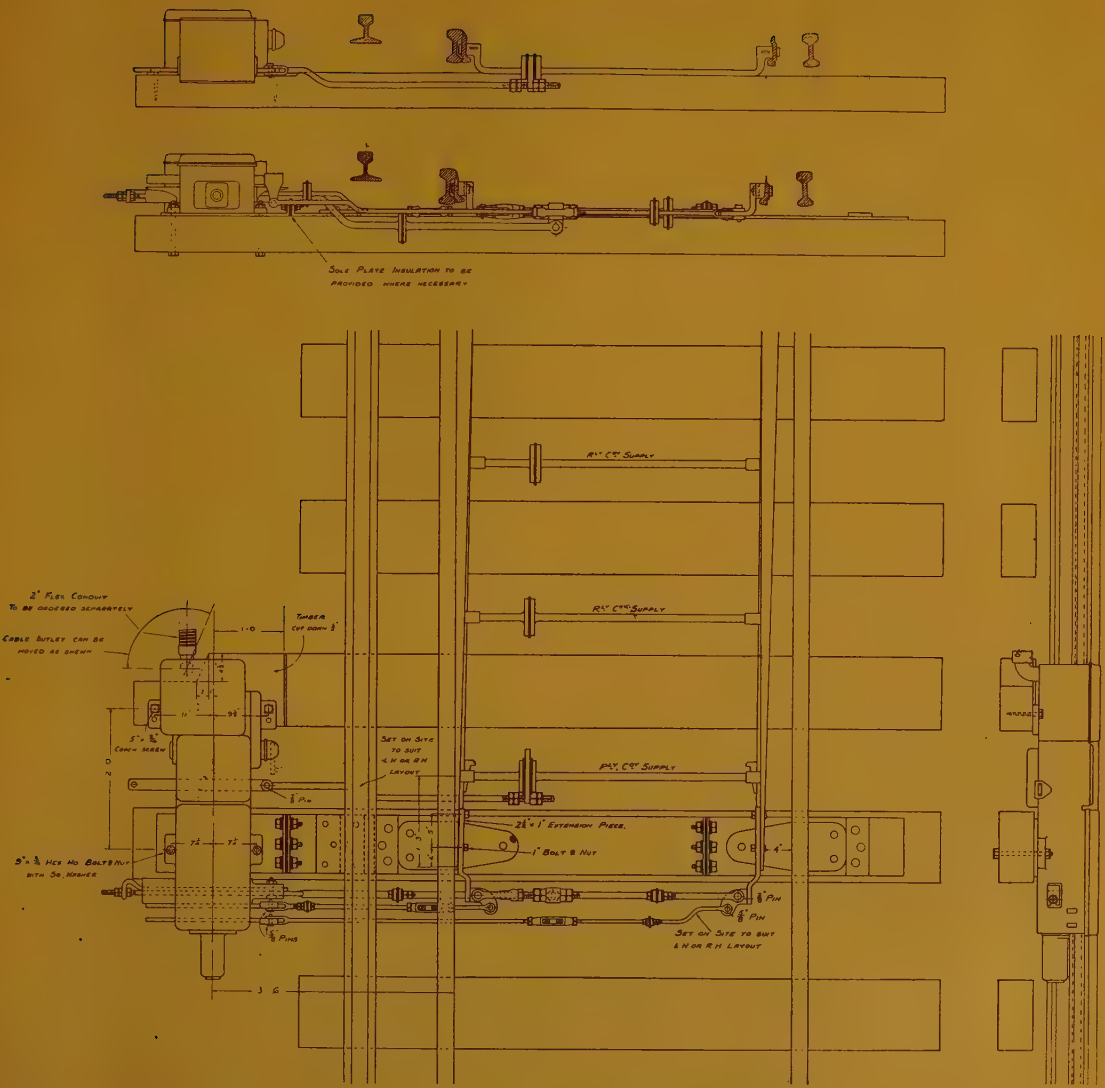


Fig. 6. — Layout of power worked points machine, insulated force rods, electrical point rods and insulated tie, or sole, plate. The facing point lock is in the machine. Charing Cross and Cannon Street, Southern Railway.

The rotary movement of the electric motor is transmitted by a train of three gear wheels to a spindle, on which is a worm gear which engages with the teeth on the periphery of a gear wheel, arranged to revolve in a horizontal plane, the rotary motion of which is transformed, according to the direction of rotation of the horizontal gear wheel into a straight thrust or pull movement by means of a crank arm fixed to the axle of the horizontal gear wheel. At the free end of

TABLE II.

Energy used and time taken to work points.

DESCRIPTION OF POINTS.	Distance from signal box, yards.	Number of points.	Number of machines.	Supply voltage, volts.	Current (amperes).		Time taken, seconds.
					Starting.	Running.	
Single ended points	50	1	1	145	10	3.0	3.0
Single ended points	500	1	1	145	10	3.4	3.0
Double ended points . . . , ...	10	2	2	145	18	7.0	3.0
Double ended points . . . -	750	2	2	145	13	7.0	3.5
One end double and one end single.	600	3	2	145	14	6.0	4.5
Both ends double.	87	4	2	145	18	8.0	4.0
Turntable bolt	...	...	1	145	8	2.5	3.0

the crank on the upper side a pin is fixed and another pin is fixed on the under side; both are so arranged that as the horizontal gear wheel rotates clockwise, the first action is for the upper pin to engage in the slide, fitted under the horizontal gear wheel and at the bottom part of the point movement. This slide is connected to the facing point lock through a slot, as the upper pin is moved round, the slide moves forward and withdraws the plunger from the facing point lock. Secondly, the pin on the under side of the crank arm engages with the slot of the slide to which the point tongues are connected and moves this slide to the right and the point tongues are thereby forced from normal to reverse. Thirdly, the upper pin again engages with the facing point lock slides and forces the facing point plunger into the facing point lock, thus completing the movement of the points.

On the facing point lock slide is fixed a rack gear, which engages with a small cogwheel : as the slide moves forward or backwards, this cogwheel is rotated and the cams which are fixed on the same spindle as the cogwheel, rotate and make various contacts : *a*) the indication; *b*) the power circuit current for working the motor; *c*) the contact springs of the point and facing point detectors and repeaters in the order and sequence to give the correct indications in the signal box, according to the position of the point tongues, cut off the current when the points have completed their movement and to set up the motor contacts for the next movement in the opposite direction.

Table II gives particulars of the horse power, voltage, current, time taken, etc., necessary for working the various functions.

Figure 3 is a typical circuit diagram of the connections between the lever and the point movement. A cable containing five wires is used for single ended points, and a seven wire cable for double ended

points. Maconite insulation is used in all cases and the coverings of each wire in the cables are of different colours for the purposes of identification. The circuit for working the points is normally disconnected at the lever contacts in the frame, but the indicators behind the levers are continuously showing the position of the point tongues : N, normal; R, reverse, or blank when the point tongues are in an intermediate position. The principle of permanent indication for the position of the points is adopted, but the lever is normally locked electrically and is not free, although the road is clear, until the catch handle contact is operated by the signalman, when if the track circuited section at the points is clear, the electric lock will be released, the point lever be free and the signalman can reverse the points. A direct current at a voltage of 110 to 140 volts then passes from the bus bar through lever contacts to the left-hand field magnet coil, through the armature and back by the return wire in the cable.

Figure 4 shows the wiring circuit diagram for a double ended pair of points.

The direct current supply voltage at the bus bar for working the points varies from 110 to 140 volts, but if the points are a long way from the signal box there will be a drop of potential in the connecting wires. To allow for this drop, the specification called for the point machine electric motors to work at a drop of potential of from 90 to 110 volts. At the lower voltage, the point movements will be slightly slower than at the higher voltage, but it has been found advisable to work the points at as low a voltage as possible to avoid the effects of the overrun of the motor on the completion of the movement.

Electrical detection has been installed on all points and facing point lock bolts. It has been arranged that the point tongues must be within one-sixteenth of an inch of the stock rail and the facing point lock bolt in, before the lever of the signal governing the route can be pulled to the clear position.

An alternating current double element polarised vane line relay in the relay room under the signal box records whether the points lay : 1. Normal, 2. Intermediate, or 3. Reverse. If the points lay normal and bolt in, a current passes from mains through contacts in the detector connected with the point tongues and the facing point lock to the line coil of the double element alternating current polarized point repeater relay in the signal box, which current reacting with the current in the local element of the relay, causes the vane of the relay to rise and make the normal contacts of the line circuit. If the point tongues do not get within one-sixteenth of an inch of the stock rail or the facing point lock is not in, the vane of the relay will remain in the central or intermediate position with the consequence that, the point detector repeater contacts will not be made, no current will pass through the line coil of the repeater relay, the indication behind the lever will be blank and no N or R is exhibited. This tells the signalman that the points have not completed their movement. If the points lay in the reverse position, the phase of the alternating current to the line coil of the alternating current point detector repeater relay is changed through 180° and the vane of the relay is forced downwards causing the normal contacts to break and the reverse control contacts to make.

All point detector repeater relays are placed in the relay room under the signal box, as are the track circuit relays or track circuit repeater relays for the convenience of having all the signal and other control circuits in the relay room, so that in case of a fault it can easily and quickly be detected. This practice has given every satisfaction everywhere I have used it.

The point machines have as far as possible been placed in the six-foot besides

the running rails and near to the points they are to work, in these cases the facing point plunger and electrical point detector contact rods are combined in the point machine which is of the Westinghouse « M » type. This arrangement has the advantage as regards the permanent way department of keeping the mechanism in the four-foot at a minimum. The lay-out of the points and point movement is shewn in figure 6.

It is not always possible to place the electric point machine in the six-foot space near the point tongues. The facing point locks of the standard pattern are then fixed in the four-foot, and the electric point machine is placed in the six-foot space as near to the points as possible, sometimes two or three roads away, and the electric point machine is connected to the stretcher rod and point detectors by means of point rodding in the usual way. Figure 6 illustrates the points and facing point locks, electrical point detector rods in the four-foot, the point movement is separated from this by three roads.

Track circuits.

All the running lines in the whole area have been divided into sections suitable for traffic working and alternating track circuits installed for automatic or semi-automatic working. The single rail alternating current track circuits are condenser fed, the double rail alternating current track circuits are transformer the double element vane type and are immune from interference from the traction power return direct current in the rails.

The energy for working the alternating current track circuits is taken from the 110-volt signal mains through No. 16 standard wire gauge copper wire, insulated white Maconite insulation; in the case of the single rail condenser fed track circuits to a small one to one transformer and for double rail track circuit to a small 110 to 7 to 10 volts transformer.

In the single rail track circuits the current from the secondary one to one transformer passes at a voltage of 110 volts through a variable condenser of from 10 to 19 microfarads capacity to one rail of the section, it passes through this rail to the other end of the track circuited section, then through the track circuit coil of the alternating current relay to the opposite rail and back by this (opposite) rail to the return side of the secondary of the small transformer. The voltage absorbed by the condenser is about 106.5 volts, leaving 3.5 volts across the rails of the track circuit. The condenser acts as a high regulating resistance.

If a train or vehicle runs on to the track circuited section, the current passes through the wheels and axle, instead of through the track coil of the track circuit relay, which is then de-energized and the vane falls to the stop and the contacts of the control circuit relays are disconnected.

The track circuit relays consist of 1. two coils which are mounted as an electric magnet and forms the electric system of the relay : *a*) one, the local coil receiving current from the 110-volt mains, and *b*) the track coil through which the current, at about 2.5 volts, from the track circuited rails, passes; 2. an aluminium vane, which is mounted on a spindle, and can partially rotate in a vertical plane, the vane is placed between the pole pieces of the two coils; 3. a set of contacts which are connected by a system of levers to and operated by the vane. When currents of the same periodicity, 75 cycles per second, and in the correct phase relationship (90°) pass through the two coils, a magnetic flux passes from one pole to the other through the vane and induction currents are generated in the vane. These induction currents create a magnetic field *a* around the vane. There are already two magnetic fields *b* and *c* between the pole pieces of the coils due to the currents that are passing through the coils. The magnetic fields *a* and

(*b* and *c*) re-act upon each other, so as to rotate the vane in the vertical plane and lift it upwards, until it reaches the stop which consists of a small roller on a light spring; as the vane rotates it acts on a system of levers which closes the contacts of the control circuits. The current through the local coil is kept permanently passing, but the current through the track coil depends upon whether the track circuited section is occupied or clear. If clear, the current passes through the track coil and the vane is up and contacts made, but if the track circuit is occupied, the current is shunted from the track coil, consequently the magnetic field due to this coil disappears and the vane rotates and falls by gravity to the down position, and in doing so the contacts of the control circuits are broken. The result is that both magnetic fields *a* in the vane and (*b* and *c*) in the coils must be acting at the same time or the vane will fall to the bottom stop which is the safety position as the control circuits are then placed in the « danger » position.

Table III gives the recorded measurements on some typical alternating current track circuits. It will be seen that in record No. 1, table III, that the drop of potential on the terminal of the secondary of the small transformer is 105 volts, but the drop of potential on the rails at the feed end is 2.5 volts. At the relay end of the track circuit the drop of potential is 2.35 volts showing a fall of potential of 0.15 in the rails themselves. The drop of potential at the track circuit relay is 1.7 volts, thus the voltage lost in the leads is 0.65 volt.

The train shunt resistance that will shunt sufficient current from the relay to cause the vane to fall and break the control contacts is on an average 1.0 ohm. If the resistance of the train wheels is higher than that, through sand for instance, the current through the relay will not be decreased sufficiently to cause the vane to drop and a false clear indication is given. It will therefore be seen that it is important that the rails should be kept clean and free from sand or grease.

It is found that the use of manganese rails has not materially altered the conditions of track circuit working. The track circuits have, of course, to be adjusted to the new conditions. Coach screws, providing they do not go completely through the sleeper, have also not caused any great difficulty with the track circuiting, but the through bolts have certainly added to the difficulty of maintaining track circuits efficiently; with care and adjustment, the difficulty can be overcome. However, their use is to be deprecated.

In addition to the track circuit current in the running rails (which is very small) in electrified areas, the running rails are used for the return traction current and in many places the running rails are of insufficient conductivity to carry the return traction current without too great a potential drop in the rails. To overcome this difficulty, additional rails are laid parallel with the running rails and connected to them to lessen their resistance or increase their conductivity and thus to avoid an undue potential drop in the rails. Therefore the electrical engineer requires both running rails for his return current, and for those rails to be of as great a conductivity as possible, but for signalling and track circuiting it is necessary to insulate the rails into sections. It is for the signal engineer to meet these conditions or make some compromise.

For this purpose the railway lines can be divided into two kinds :

1. Where there are points and crossings, generally within station limits;
2. Where there are no points or crossings, generally between stations.

Under 1. it is arranged that the one rail is allotted solely to the track circuit and is called the track circuit rail and is divided into insulated sections. Whilst the other and opposite rail is continuous

TABLE III.

Alternating current track circuits : test sheet (Southern Railway).

—	RECORD OF TEST. 1	2	3	4	5	6
1. Date	8 August 1926.					
2. Station	Cannon Street.		Met. Jct.	Charing Cross.		
3. Track circuit number.	16	45	Y	30	29A	17
4. Road	...	...	...	Middle.	Middle.	Up local.
5. Temperature (hot, warm, cold, frost)	Warm.	Warm.	Warm.	Warm.	Warm.	Warm.
6. Weather	Fine.	Fine.	Fine.	Fine.	Dry.	Dry.
7. Length of track circuit	...	126	700	240	250	300
8. Length of relay leads and gauge of wire (yards).	45 × 2	200 × 2	50 × 2	210 × 2	40 × 2	170 × 2
9. Length of feed leads and gauge of wire (yards).	15 × 2	42 × 2	20 × 2	20 × 2	25 × 2	7 × 2
10. Single or double rail track circuit.	Single.	Single.	Double.	Single.	Single.	Double.
11. Relay number and type	W 2366	W 2383	W 2463	W 2605	W 2598	W 2528
	Double element vane.			...	...	...
12. Description of relay	Condenser.	Condenser.	Reactance.	Condenser.	Condenser.	Reactance.
13. Regulating resistance.	15MF	16MF	3.6	19M	19M	4.4
14. Description of resistance.	...	...	...	...	...	...
15. Parl. resistance at relay (ohms).	2	2	...	2	2	...
16. Description of above	22DCC	22DCC	...	22DCC	22DCC	...
17. Impedance coil at feed	...	...	...	...	...	...
Primary.						
18. Electromotive force, feed end	110	108	105	103	107	107
19. Electromotive force, relay end	110	110	105	107	107	107
20. Current, feed end (amperes).	0.84	1.3	0.37	1.05	1	0.48
21. Current, relay end. (amperes)	0.34	0.315	0 3	0.32	0.31	0.31
Track circuit clear.						
22. Electromotive force across transformer	105	125	8	97	105	11.4
23. Electromotive force across condenser or reactance	105	125	8.5	95	102	10.2
24. Electromotive force at feed fuses transformer side.	2.55	4.35	2.85	6	2.8	2.55
25. Electromotive force at feed fuses track side	2.6	4.35	2.55	6	2.75	2.45
26. Electromotive force at feed end of track	2.5	3.95	2 45	5.8	2.45	2.3

TABLE III (*continued*).

—	RECORD OF TEST.					
	1	2	3	4	5	6
Track circuit clear (continued).						
27. Electromotive force at centre of track	2.4	3.95	2.45	5.75	2.3	2.2
28. Electromotive force at relay end of track	2.35	3.95	2.3	5.5	2.2	2.15
29. Electromotive force at relay fuses	1.7	2	2.15	1.95	1.85	1.75
30. Electromotive force at relay terminals	1.7	2	2.1	1.9	1.8	1.75
31. Current from transformer (amperes).	1	1.3	2.35	1.4	1.2	2.45
32. Current through condenser or reactance (amperes).	1	1.3	2.35	1.4	1.2	2.45
33. Current through parl. resistance at relay (amperes).	0.78	0.86	...	0.95	0.93	...
34. Current to track (amperes).	1	1.3	2.35	1.4	1.2	2.35
35. Current through relay (amperes).	0.18	0.195	0.23	0.23	0.2	0.25
Track circuit occupied.						
36. Electromotive force across transformer	105	126	8.5	103	104	11.3
37. Electromotive force across regulating resistance.	105	126	8.5	102.5	104	11.3
38. Electromotive force at feed fuses (transformer side)	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
39. Electromotive force at feed fuses (track side)	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
40. Current from transformer (amperes).	1	1.3	2.4	1.25	1.2	2.35
41. Current through regulating resistance (amperes).	1	1.3	2.4	1.25	1.2	2.35
42. Current through impedance coil (amperes).	...	...	...	...	...	...
43. Current to track	1	1.3	2.4	1.25	1.2	2.35
Feed fuses disconnected.						
44. Electromotive force across transformer	105	125	9	100	102	11.5
45. Electromotive force across regulating resistance.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
46. Electromotive force across track fuses	105	125	9	180	102	11.5
47. Current from transformer (amperes).	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
48. Current through impedance coil (amperes).	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
Relay disconnected.						
49. Electromotive force across transformer	103	125	8.5	97	100	11.5
50. Electromotive force across condenser or reactance	100	122	9	80	92	12.5

TABLE III (*continued*).

—	RECORD OF TEST.					
	1	2	3	4	5	6
Relay disconnected (continued).						
51. Electromotive force at feed fuses (transformer side)	23.5	23	2.9	50	36	2.75
52. Electromotive force at feed fuses (track side)	23.5	23	2.9	50	36	2.75
53. Electromotive force at feed end of track	23.5	22.8	2.7	50	36	2.65
54. Electromotive force at relay end of track	23.5	22.5	2.55	50	36	2.5
55. Electromotive force at relay fuses	22.5	22	2.45	50	36	2.18
56. Current from transformer (amperes).	0.92	1.1	2.45	0.825	0.91	2.55
57. Current through condenser or reactance (amperes).	0.92	1.1	2.45	0.825	0.9	2.55
58. Current through impedance coil (amperes).	...	...	...	...	...	...
59. Current to track (amperes).	0.92	1.1	2.45	0 825	0.9	2.55
Shunt resistance.						
60. Feed end, drop away (volts).	0.9	0.95	0.8	0.8	0.8	0.75
(ohms).	2.5	3.5	0.6	2.05	1.1	0.5
61. Feed end, pick up (volts).	1.1	1.15	1.2	1.05	1.1	1.15
(ohms).	4	5.5	0 85	3	2	0.7
62. Relay end, drop away (volts).	0.9	0.95	0.85	0.8	0.8	0.75
(ohms).	2.6	3	0.65	2.5	1.1	0.55
63. Relay end, pick up (volts).	1.1	1.2	1.15	1.05	1.1	1.15
(ohms).	4.2	6	0.95	3	1.9	0.7
64. At relay, drop away (volts).	0.95	1	0.6	1	1.1	0.9
(ohms).	1.8	1.85	0.8	1.1	1.3	1.6
65. At relay, pick up (volts).	1.1	1.2	0.85	1.1	1.2	1.05
(ohms).	3	2.8	1	1.3	1.7	1.95
66. Insulation resistance of track circuit. (ohms).	...	...	...	...	...	...
67. Direct current leak through track circuit relay	...	...	...	...	...	...
68. Rails: weight	95	95	95	91 1/4	91 1/4	95
69. Class of chair fastenings				Coach screws.		
70. Ballast	Stone.	Breeze.	Stone.	Timber.	Timber and stone.	
71. Number of crossings	...	1	...	...	...	...
72. Number of impedance bonds	...	...	2	...	...	2
73. Conductivity of bond wire joints (as tried by telephone, etc.)	...	...	...	...	...	...
Remarks and small track circuit diagrams	...	...	...	...	...	...

throughout and is used in common for the track circuit return and the traction power current return and both alternating current 75 cycles for track circuit and the direct traction current pass through this conductor simultaneously without the track circuit apparatus being interfered with.

In the case of 2. the rails have to be divided into insulated sections for the signalling and track circuit conditions. To allow the traction power current to pass by the insulated joint at the end of each section an impedance bond is provided which provides a path of very low resistance (0.0006 ohm) between one insulated section rail and the next for the passage of the traction current, at the same time offers a high resistance to the passage of the track circuit current from one rail to the opposite rail (between 0.6 and 2.0 ohms is possible) and absolutely prevents the track circuit current from one insulated and track circuited section getting to the next.

In case the insulation of an insulated fish plate fails, it is arranged that the phase of the current in the adjacent track circuit shall be 180° behind that in the track circuit coil of the track circuit relay, so that the tendency of any stray current would be to push the vane downwards, causing it to show track circuited section occupied and acting in the safety direction as regards the control circuits.

Figure 7 is a typical track circuit diagram shewing the paths of both the currents, *i. e.*, traction and track circuit, through the rails simultaneously.

There are three general cases to consider :

1. Double rail track circuits are used where there are no points or crossings or connections between the rails.

2. Single rail track circuits are installed where there are points, crossings or connections.

3. The commencement and ending of alternating current track circuits: *a*) single; *b*) double; *c*) double to single; *d*) single rail; track circuit to the adjoining rail which is not track-circuited; *e*) double rail track circuit to rail where there is no track circuit, *i. e.*, at the end of the track-circuited section.

Resonating bonds are used throughout the Charing Cross to Borough Market area, and non-resonating bonds over the Blackfriars area on all double rail track circuits.

Take the case of the commencement of the track circuit area A. There is no track circuit on rails a and a_1, but the section B is track circuited and both rails b and b_1 are used for the track circuit and the traction return current. This class of track circuit is known as a double rail track circuit. Both rails are insulated at b_2, an impedance bond g in track circuit B is put in as near to the insulated joint as possible and the terminals are connected to both rails as shewn in the diagram. Two wires are led from the centre of the impedance bond g, one connected to rail d and the other to rail d_1. Another impedance bond h, is put in at the opposite end of the track circuit B. Similarly with track circuits C and D, but as the next track circuit to B is C, a double rail track circuit, the centres of the two bonds are connected together by two copper cables h, similarly between C and D. Track circuit E is a single rail track circuit, and the centre of the impedance bond k is connected to the rail e, by means of two copper wires or cables. The top rail e being insulated is used for the track circuit alone and the bottom rail e_1, is used as a common return for the traction return current and the track circuit return current simultaneously. Arriving at F, where there is no track circuits, a traction bond wire is installed connecting rails F_1 and F to equalize the current in the two rails, and to increase their capacity.

The paths of the traction currents are firstly from rail a to centre of bond g,

through top coil of impedance bond to rail *b*, through *h* to rail *c*, through *i* to rail *d* to *k*, thence to rail *e* to *f*, where it divides, part going through *t* to *f*, and the remainder through *f*. Secondly, from rail *a*, to centre of bond *g*, through bottom coil of impedance bond to rail *b*, through *h* to rail *c*, through *i* to rail *d*, to *k* thence to rail *e*, to *f*, and then partly through *t* to *f* and through f_1 to the traction sub-station.

There are four paths for the track circuit current to divide and pass through in double rail track circuits. In the case of track circuit B, the current comes from the secondary of the transformer *m*, through regulating resistance *q* to rail *b* and then divides 1. through impedance bond *h* to rail *b*, to fuse *n* and return side of transformer *m*, this is path one; 2. through rail *b* to *o*, and again divides, first through impedance bond *h* to rail *b*, second, through track circuit coil *p* of track circuit relay *p* to rail *b*, these two form the second and third paths, the currents then combine and pass through rail b_1 to fuse *n* and return side of transformer *m*. The fourth path is the leakage path between the rails *b* and b_1, through the ballast.

There is no electrical path for the track circuit current to pass from rails *b* and b_1 to rails *c* and c_1, as the insulated fish plates between the rails of the two track circuits insulate one from the other and there is no circuit through the connecting wire or impedance bonds.

In the case of track circuit E the whole of the return traction current passes through rail e_1, as the other rail *e* is insulated, but the track circuit current passes from the secondary of transformer *r* through condenser q_1, to rail *e*, and through rail *e* to the local coil of relay *s* and back through rail *e*, which acts as a common return conductor for the traction and track circuit return currents, to the return terminals of the secondary of transformer *r*. There is no other return path for the track circuit current except through the leakage path between rails *e* and e_1 through the ballast. The lower the resistance of the ballast or path from rail *e* to rail e_1 the greater is the difficulty of maintaining the track circuit apparatus working, as it is found in practice that in wet places or where the conditions are bad, the variations in the ballast resistance are very great, sometimes extremely low and at others very high during hot and dry weather. It is better then to put in an artificial ballast resistance of comparatively low value, so that the resultant ballast resistance remains practically constant and the track circuit is adjusted to those conditions.

It is necessary that the traction direct currents through the right and left hand coils of the impedance bonds shall be equal in value, so that as they pass through the coils in opposite directions their magnetic effect on the laminated soft iron core shall be equal and opposite, and that the soft iron core shall be unmagnetized. In this condition the core will be in the best condition for a strong magnetic flux to be induced in it, due to the track circuit current passing through the two coils in series and in the same direction and thus offer a large inductance effect to the track circuit current, consequently the impedance in the track circuit will be at a maximum. As there are in double rail track circuits, three paths, one through each impedance bond, in addition to the ballast resistance, it is necessary to insure good track circuit working to arrange the impedance of both the bonds to be as high as possible, or to so arrange the value of impedances of the track circuit relay in both local and track coils so that the train shunt resistance shall be as high as possible. Taking the ballast resistance to be 2 ohms, then if non-resonating bonds are used each with 0.6 ohm resistance, the combined resistance rail to rail, without the relay in circuit is 0.277 ohm. If resonating bonds are used, then the resistance

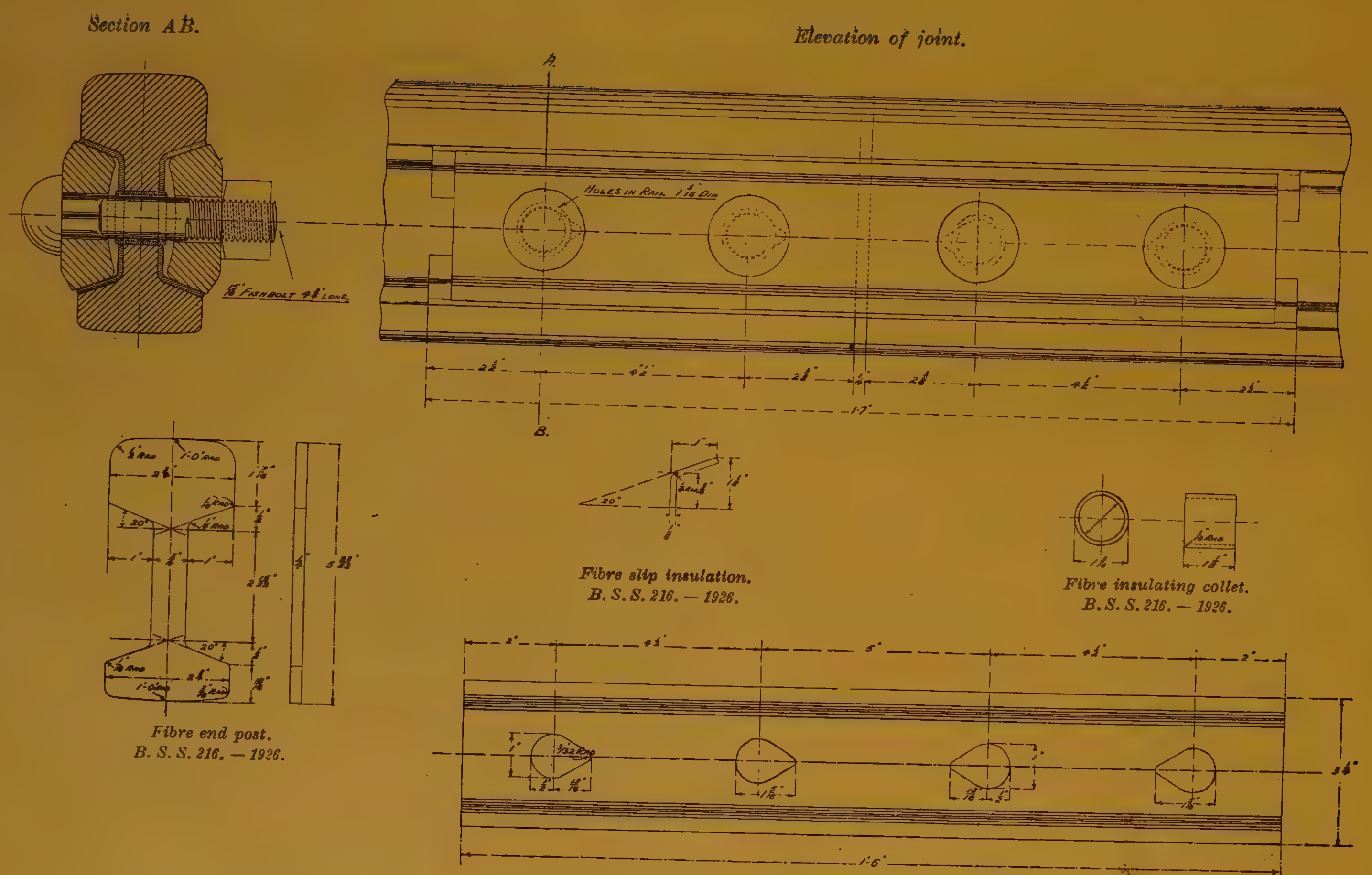


Fig. 8. — Insulated rail joint, 95 lb. B. S.

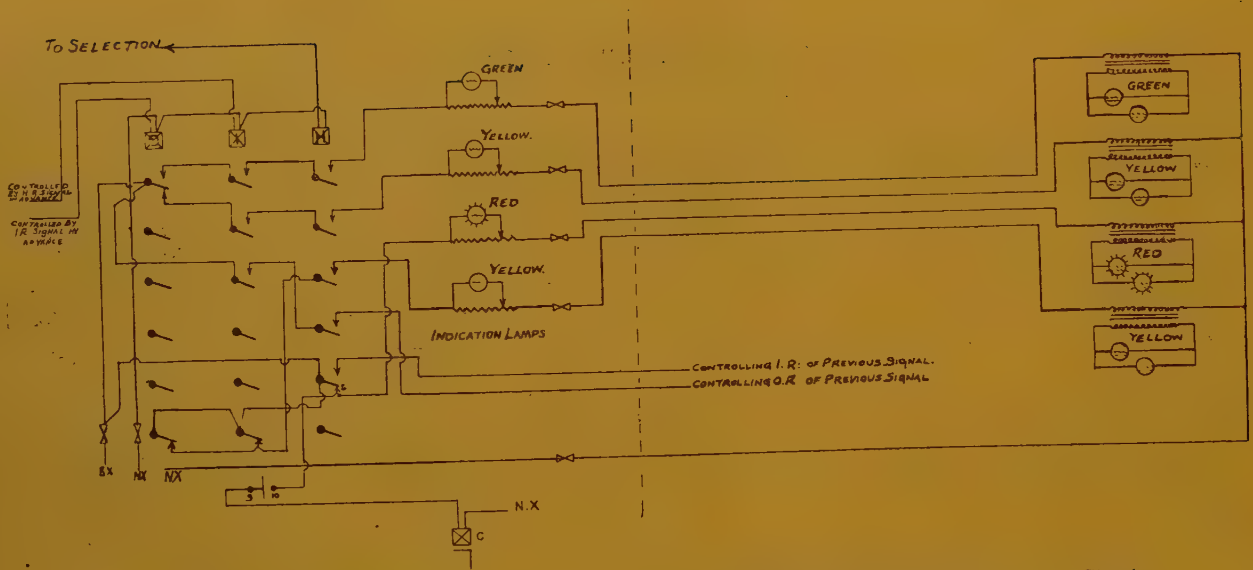
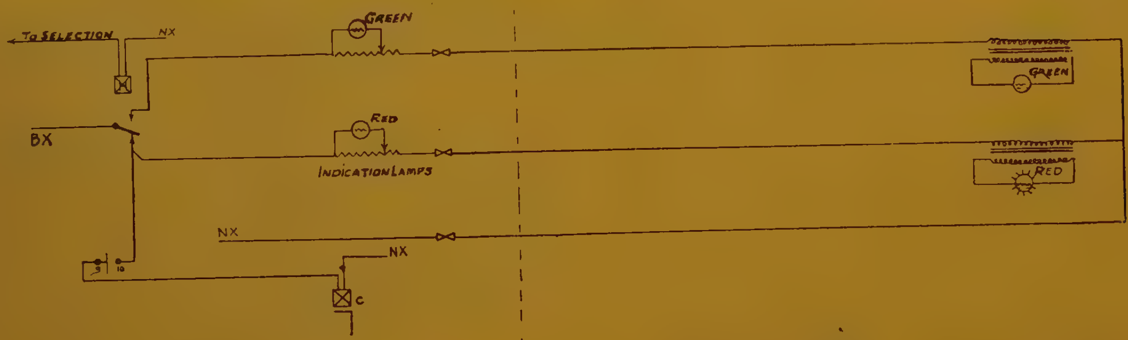


Fig. 9. — Control circuit for 4-aspect signal. Charing Cross to Borough Market Junction and Cannon Street.



In signal box. *Signal.*

Fig. 10. — Control circuit for shunt signal.

rail to rail would be 0.666 or 2.4 times greater than with non-resonated bonds. Had the resistance of the ballast been 10 ohms then the combined resistance in the case of the resonated bonds would be 0.9 ohm, and with the non-resonating bonds 0.312 ohm, that is 2.88 times greater.

When an engine or train runs on to a track circuited section, the wheels and axles form a fifth path of low resistance to the alternating current feed track circuit current, which shunts sufficient current from the track circuit coil of the relay to cause the vane to fall on the bottom stop and the indicator shows that the section is occupied.

But in cases where alternating currents are used for traction purposes and the rails used for the return traction current the comparatively high impedance of the impedance bond is a disadvantage as far as the traction current is concerned. In the case of direct current traction return, the resistance of the impedance bond from one insulated section to the next is 0.0006 ohm. Where alternating current at a frequency of 25 is used for traction, the impedance of the bond from one track circuited section to the next varies with the amount of current that is passing through the bond as shown in table IV, which shows that if a resonated bond is used, the impedance varies from 0.0005 to 0.000819 ohm, but if a non-resonated bond is installed, the impedance of the bond varies from 0.00106 to 0.001577 ohm. Thus if the return traction current in the running rails was 2 000 amperes, the drop of potential across the bond from track circuited section to the next track circuited section would be for the non-resonating bond 3.15 volts, and for the resonating bond 1.63 volts.

TABLE IV.

Test on resonated and non-resonated impedance bonds made for track circuits worked by 75 cycle-alternating current for impedance when traction current at frequency of 25 cycles has to be passed through them from one track circuit to the next. Test made on one bond.

Resonated impedance bond.			Non-resonated impedance bond.		
Current, amperes	Volts.	Impedance, ohms.	Current.	Volts.	Impedance.
50	0.025	0.0005	60	0.07	0.00106
80	0.07	0.000875	70	0.075	0.00129
135	0.115	0.00085	120	0.155	0.00129
210	0.19	0.00094	145	0.215	0.00148
245	0.2	0.00081	240	0.37	0.00152
290	0.22	0.00076	260	0.41	0.001577
360	0.275	0.000819			

Curves for resonated and non-resonated bonds plotted from the records of practical tests given in table IV, show that the impedance of the non-resonated bond is approximately twice that of the resonated bond under the conditions from 25-cycle alternating current.

For traction purposes the additional

conductor rail *z* has been laid between *h* and *i* and connected to the centre connections between impedance bonds joining *b-c*, and *c-d*. Thus the traction current now passes through the rails *c*, c_1, and e_1, and raising the conductivity for the traction current approximately 50 %. The additional rail can only be connected to the running rails where double rail track circuits are installed at the ends of the double rail track circuits. In the case of track circuit *e* the additional rail can be connected to the common return rail at any points along its length and at the ends. In this case the track circuit return current passes through the additional rail as well as the running rails, but in the case of the double rail track circuit and additional rail the track circuit current is not affected.

Insulated fish plates.

The insulations used for insulating one track circuited section are of the simplest type as shown in figure 8. It consists of four strips of railway hard grey fibre bent as shown in figure 8. The strips are all of the same size and pattern, and fit the top and bottom of the web of the rail on both sides. There are the usual end pieces and collets through the rail. This type of insulation avoids drilling holes in the fibre, is easy to change if necessary, and experience on other parts of the line shows that it is efficient and lasts quite as long as insulations of other types. The secret of long life in these and all other insulated fish plates is to keep the joints tight up to the rail. If this is not done a grinding action is set up, as each wheel passes over the joint, and soon grinds it out.

There being no holes in the fibre for the fish-plate bolts to pass through from fishplate, web of rail, and fishplate on other side, allows the rail to expand, contract, or creep without affecting the fibre in the least. This is a distinct advantage, the expansion, contraction or creeping of the rails cannot injure the insulations.

All-electric power signal frames.

The 140-lever signal frame at Cannon Street, and the 100-lever signal frames at Charing Cross are of the Westinghouse Brake & Saxby Signal Company's well-known make, small catch handle levers are used to operate the mechanism. The mechanical locking is arranged in a vertical plane under the signal levers and in the front of the frame. Owing to the quantity of the locking, the locking table is carried about 2 feet below the floor level. The electrical locking is arranged and placed in a horizontal plane at the upper and front part of the frame. The electric locks are similar to those used in the Westinghouse electro-pneumatic signal frame, but the locks have been modified to work in the all-electric signal frame.

The top part of the levers when operated moves four inches to the check lock position, and then three inches, to complete the movement of the levers. The signal levers are pulled completely over to get the signal to the pass condition, that is, single or double yellow or green without pulling to the check lock position first, and then completing the move, but on replacing the signal lever to the « on » position, the lever cannot pass the check lock position until the signal has gone to the « on » condition. The point levers are first moved to the check lock position in both the over and normal movements and when points have moved completely over in response to the movement of the lever and the bolt lock is in, then a current passes from the point detection springs to the repeater relay in the cabin which controls the circuit of the electric lock and the check lock is released and the signalman can then complete the movement of the lever either to the reverse or normal positions as the case may be.

The aspect displayed at the signal is repeated on the indicators immediately behind the lever operating that signal,

thus if the signal aspect is red, a small red light will appear in the indicator. Similarly for a yellow, double yellow, or green aspect. In the case of the point levers either the indication N or R, or both blank is exhibited behind the lever according to whether the points lie normal or reverse or in an intermediate position. If no light is shown in the signal indicators behind the lever, it tells the signalman that no light is being exhibited in that signal; if the light is about 50 % as bright as normally, the signalman is told one of the filaments of either the main or side light lamp has broken or burnt out; if approximately the indication is only 25 % as bright as usual it intimates to the signalman that either the main or side light lamp has gone out. In case of the points, if both indicators are dark and no N or R is showing on the indicators behind the point lever, the signalman knows that the points have not completed their movement and that they lie in an intermediate position. The indications behind the signal and point levers are permanently exhibited, but the electric locks only released, when the catch handle is pulled, which action has the effect of connecting the contacts fixed on the catch handle. Thus the electric locks are only released momentarily when the lever is about to be moved. In addition to the signal lever being locked electrically, the signalman can see by the position of the train on his illuminated diagram, whether his point levers are track locked or free and when to pull or replace his lever.

Figure 9 shews the typical circuit diagram of connections of a four-aspect colour light signal complete. It will be seen that the lever is now in the normal position, back in the frame, and a current is passing from bus bar 1, to fuse 2, connecting wire 3, to back contact 4, leading wire 5, to 6, 13 and 11, to 12 and 7 through the primary of transformer 8 to return 9 to return bus bar 10.

The voltage on this circuit is 110 volts, as the energy is taken from the signal supply bus bars. At 6, an adjustable resistance 11 is inserted in the circuit and a fuse 12, the indication lamp 13 is connected across this resistance and the voltage so adjusted that it is 7 volts. The indication lamp is placed behind the signal lever in the signal frame and forms the repeater of the red light in the signal. The resistance of this lamp hot is 26.9 ohms. This voltage should be considerably lower than the working voltage of the lamp and the latter should be under run as the momentary current at start is much higher than the normal current, owing to the back electromotive force of the transformer and the inductance of the resistance coil not being operative immediately the circuit is made. The effect can be reduced by arranging that the R is non-inductive.

The drop of potential on the transformer primay is 90 volts and on the secondary or lamp terminal 5.5 volts and the current through the lamps 14 and 15, is 5.2 amperes; 14 and 15 are the two 18-watt candle-power lamps for giving 14 the main beam, and 15 the side light.

For the single yellow to be exhibited, relay H must be operated, this disconnects the back contact of 4 which now makes on the top contact of 4 and a current passes to the next signal behind to operate the I relay at this signal so as to give a double yellow at that signal, at the same time contact 16 is made which has the effect of causing the single yellow light of the signal under discussion being illuminated. If the next signal ahead was in the double yellow condition relay 1 would be operated and contacts 17 and 18 closed with the consequence that a current would pass through from 1, 2, 19 back contact 17, 18, 20 and 21, the primary of the transformer of the second yellow light and then both the yellow aspects would be showing. If the signal ahead were exhibiting a double yellow condition the 0 relay would be operated and the back contact of 19 would be bro-

ken; also 26 and 27 bottom contacts are broken, resulting in the second yellow light going out with the consequence that, relays I and H being operated, a current will pass from 1, 2, 19 top contact, 22, 23, 24 and 25, and the green aspect will shew. Directly the train or engine gets on the track circuit ahead of the signal, the relay H, which is controlled by the selection or control circuit is de-energized and the H relay contacts are disconnected with the result that the current is cut off the green lamp and as contact 4 is now making on the back contact, the red light is immediately illuminated and the danger or stop signal exhibited.

The circuit diagram of the shunt signal is given in figure 10. The indication behind the signal lever and the transformer at the signal perform the same functions as the running signals, but only one double filament lamp is used instead of two in the running signals.

The lamps in the shunt signals are 24 watts, 6 volts, 4 amperes, 45 candle-power.

Maintaining the light in the colour light aspects continuously is of the greatest importance : it is very dangerous for a signal aspect to go out, as if it did, the driver would have no signal, nor be able to see the position of the signal post at night-time, and therefore every precaution possible has been taken to prevent the signal light being entirely out. First, the lamps used have two filaments in parallel and both are alight at the same time. If one filament burns out the second filament remains to give a light which will of course be less brilliant than the light given off by two filaments. This is in accord with the recommendations of the Ministry of Transport Committee on Light Signals, that when the first light (or filament) goes out, the subsidiary light shall give approximately only 50 % of the ordinary beam, so that it should be noticeable to the driver, and that he shall call attention to it. The lamp should be replaced at once by another, as all the time the first filament is broken you are depending on one filament only, and should that burn out there would be no main beam. As a side light has been provided in each colour light aspect, when the driver arrived at or near the post he would see the side light very distinctly and therefore would not be entirely without a signal aspect. Experiments shewed that the lamps would burn for more than 2 000 hours, and as a safety measure, the lamps in the red aspects are changed after having been run 750 hours : the lamp can then be used on some other less important signal aspect.

Where the normal condition of the block is danger, the red aspect lamp will be burning approximately from 85 % to 95 % of the day; they will therefore burn out in use, in a shorter time than the lamps in the other aspects. Further, it must be borne in mind that the red aspect is the most important, and the lamps should always be in good condition.

The fact that one filament or both filaments are out is intimated to the signalman by means of the indication lamps behind his lever in the frame, as when one filament is burnt out less current is taken from the supply to the primary circuit and consequently less current passes through the adjustable resistance and primary circuit (see fig. 9). The voltage across the adjustable resistance is reduced from 7 volts to 4.5 volts, which causes a diminished light to be given in the indication lamps behind the levers in the frame. If both filaments burn out the current will fall further, and a diminution of light given by the aspect will also be smaller with the result that the voltage falls to 1.1 volts and the lamp practically goes out.

The signalman seeing the various diminution of lights and by comparing with other lights in the frame, knows that the electric indication lamp is faulty, and sends for the lineman who deals with the matter early.

Thus the precautions taken are :

1. Providing double filaments.

2. Arranging to change the red lamp every 750 hours.

3. Driver seeing the smaller light reports to the signalman.

4. Providing indication lamps behind the signal levers so that signalmen may know as quickly as possible of any light actually going out.

5. Providing a second lamp for a side light will give sufficient light to a driver when the main light has gone out, to enable him to distinguish the colour aspect signal, especially when he reaches the signal post.

An illuminated spot light signal diagram has been provided and fitted up behind and above the signal frame. The diagram shews the lay-out of all the running roads under the control of the signalman with anything special in the areas immediately adjoining his section. The track circuited sections of the line appear on the face of the diagram in different colours. Approximately in the middle of each track circuited section a round hole is cut out of the face of the diagram through which, if the track circuit represented is clear, a white light shines, but if the track circuit is occupied the light disappears and leaves the hole dark. The lights are operated automatically by the trains passing on or off the track circuits by means of the control contacts of the track circuit relays in the cabin.

The diameter of the small holes is one inch, and the small incandescent lamps are 5 candle-power, 12 to 14 volts, 0.24 amperes, and 3-6 watts.

It is necessary that the illuminated diagram shall be protected from too strong an extraneous light from the sun or lamps in the signal box, or it will be reflected back to the signalman, and have the effect of preventing him seeing the indication. This is more marked where the front of the diagram is glazed, but can be overcome by lightly stippling the window panes with white paint, or tilting the diagram itself sufficiently so that the reflected light does not shine on the signalman's eyes.

Four aspect colour light signals.

The four lamps forming the four aspect colour light signals are mounted on a back plate, which acts as a background to the aspects. Each of the lamps consists of an aluminium case for the sake of lightness, in the front of which is fixed a clear glass Fresnel or step lens, 8-inch diameter, behind this clear lens and 2 1/8-inches distant from it, a coloured green, yellow, or red inverted step lens, or one with the steps on the convex side of the lens called a Torric lens, is fixed. These two lenses collect all the rays of light from the source, that falls on the back of them and the beam passes out of the front of the clear lens, in parallel rays. The rays will only be parallel if the source of the light is very small, theoretically a point, and all the light must be concentrated in the small filament, as the light outside the focus is very inefficient. Double filament focus electric incandescent lamps are used, the filaments are wound in a spiral, 3/16-inch long and are arranged side by side. One of the filaments is placed in the focus of the lens, the second filament will therefore be just outside the focus. The two filaments together give 30 candle-power, 18 watts, 6 volts, 3 amperes being consumed in producing the light. If one filament burns out, the second filament acts as a stand-by and gives out a diminished quantity of light; the result of this is : 1. the light signal aspect is not out; 2. the driver sees that the light aspect is not so brilliant as usual and calls attention to the matter; 3. reduces the light in the indicator behind the lever in the signal frame and the signalman's attention is drawn to the matter. If both filaments are broken or burnt out, the main beam

will of course be out, and the driver will not see it, but as he comes up to the signal aspect, he will see the side light, thus the side light acts as an auxiliary lamp under these circumstances. As the filaments are larger than a point, some of the light that passes out of the lens will be dispersed slightly, in fact the spread of the beam varies from 2° to 5°. In cases where the lines are on a curve, spread lenses giving 20 %, 15 %, 10 % spread are fitted over the front of the plain 8-inch lens; of course the more the light from the plain lens is dispersed into a wider beam, the less will be the intensity of the beam of light.

In practice the driver can see the main beam plainly and distinctly more than 800 yards away, but as the light is concentrated in a beam of parallel rays when he gets close to the signal post, he will not see the beam, especially if the signal post is placed more than 2 ft. 6 in. from the outer running rail, as the beam will either pass over, or by the side of him. As he is authorised to come right up to and parallel with the signal post, he should be able to see the aspect exhibited at the post when he has come up to the signal post and is at right angles to the post. This is accomplished at Cannon Street and Charing Cross by means of a side light, which gives a bright and distinct beam of light at right angles to the main beam, or at any other angle upwards, downwards, or sideways, in fact it can be adjusted to give a side light in any direction desired, so that the side light can be seen by the driver in whatever position he may be relative to the main beam. The side light is given by a second lamp, so that in each coloured aspect signal there are two lamps, one for the main beam and one for the side light beam.

In some cases an additional deflecting prism immediately behind the front clear lens is used to deflect a part of the main beam away to the left or right to give the driver a side light. Sometimes the prisms are placed in the centre of the lens, as it is thought that the light can be best spared from the centre; in other cases the prisms are placed in one quadrant of the front 8-inch clear lens. When the quadrant is not brilliantly illuminated in the main as the other quadrants, this is more noticeable at a distance from the signal, but when the prism is placed in the centre of the front lens the black spot in the centre is more conspicuous when the driver is nearer to the signal. In both cases the effect on the main beam is more pronounced during foggy weather when the maximum light from the aspects is required. Obviously, if light is deflected from the main beam, the latter cannot be so intense. It may be said that two lamps, one for the main and another for the side light is costly, but in both cases a good and brilliant light is wanted for both the main and side indications, and to keep both up to the requirements requires sufficient power. Further, if the electric lamp on the signal aspect breaks or goes out, the signal aspect is quite dead, whereas with the side light used at Cannon Street and Charing Cross, if the main beam light goes out, the driver has the side light to tell him the aspect that is being given or if the side light goes out, he has had the benefit of the main beam.

Each aspect has a small hood to protect it from the rays of the sun, but the hoods are so shaped that they do not interfere with the driver's view of either of the aspects. It has been arranged as far as possible that the four aspects shall be as near to the driver's line of sight as he stands on the footplate of his engine, this is 11 ft. 6 in. above the level of the rail. In many cases this cannot be done and the aspects have to be placed above or outside the gauge line. In some cases had the ordinary arrangement of four aspects one above the other been applied, the aspects would have been excessively high. To avoid this, the four aspects have in these cases been arranged

in cluster form. This enables the aspects to be brought nearer to the driver's line of sight than when all arranged vertically

It is found that if you have coloured glass, however protected, some phantom light can be observed, when the conditions necessary are set up. Placing the clear glass lens in front of the coloured glass lens practically does away with these phantoms as far as the driver is concerned : but in any case if the sun shines directly on to the lens, there will be a phantom coming from the lamp, which will be seen by anyone looking directly into the signal aspect.

Phantom lights are not only derived from reflections from the sun. It must be remembered that all glass, enamelled signs and polished metal act as reflectors more or less so under different conditions, and these powerful signal lights, if shining on to, say, a window glass, will reflect back a beam that can be seen by anyone happening to be standing on the line of the angle of incidence or reflection. For instance, a red light from a starting signal shining on and being reflected back from a window of the station building might, providing the conditions are favourable, be mistaken for a buffer stop light by a driver, instead of the actual buffer stop. A white, yellow, green or red, or other coloured light may be deflected from an enamelled advertisement.

It might happen that the light from an aspect for the down line under favourable conditions be reflected in the driver's look-out glass window in the cab of his engine, especially so at a time of darkness. The image would of course not be so brilliant as the aspect itself, but these conditions can be avoided by taking care when setting out or installing the system. The same remarks apply to the ordinary signal lamps, but they are of course not so intense.

There can be no doubt that coloured glass lenses alone cannot be used for signal aspects on account of the phantom lights that are always showing when the sun is out, or even in daylight, consequently a front clear lens or a cover glass etched or otherwise is absolutely necessary.

Shunt signals.

Two colour aspect light signals have been adopted for shunting purposes : red for stop, green for proceed as far as the line is clear. In nearly all cases the shunt signals have been arranged to be on the ground level, unless they are on a post which carries running signals.

The two shunt signals are mounted on one stand, red at the top, and green just below it. It was desired to make a definite distinction between the size of the running and shunt signals, the former had lenses 8 inches diameter, and the shunt signals 2 inches, with coloured lenses only, but through the difficulty caused by phantoms, 4-inch lenses were agreed to, and the front of the coloured lenses were etched or slightly frosted. This had the effect of considerably diminishing the light, and an arrangement of a coloured glass lens, red or green, with a separate etched clear glass in front of it which gives a sufficient main beam, and spreads the light at the same time, both to the right and left, is being substituted.

In the case of the shunt signals, it was found that a brilliant beam of light did not meet the conditions, as the beam could only be seen by the drivers when they were on that line. As they often started from an adjoining road, the drivers could not see this class of beam light until they got near to the signal. Arranging the clear etched glass in front of the coloured lens, causes the light to spread in all directions and the signal can be seen over a very wide angle and meets the requirements.

Automatic signals

The wiring of the automatic signals between Waterloo and Metropolitan junc-

tion is on the same principle as the semi-automatic signals at the stations, but an illuminated letter « A » on a black background is fixed to each automatic signal post for the information of the driver in case he has stopped at it, owing to the signal being « on ». In that case, after he has stood there one minute he has to go to the telephone placed near to the post and get into communication with the signalman in the box next ahead of the position and await instruction. The telephone is fixed about 11 ft. 6 in. above rail level, and the outside of the cases have black and white stripes painted on them diagonally to ensure they can be easily found.

Route signalling.

The ideal signal to a driver is a single aspect and this is easily given under the four-aspect light signal system for straight running lines, but at diverging junctions the practice hitherto has been to provide a signal for each route at the junction, and in many cases to provide a distant signal for each route to tell the driver which route the line is set for him to travel over. If this system is followed, the number of different aspects exposed at one time is sometimes as high as 17; this means taking the semaphore for day and lights by night, 34 different aspects for a driver to know and determine the route he has to pass over.

Under the four-aspect colour light signalling scheme : 1. it can be arranged to have only the four-aspect signal at the diverging junction and by means of the single yellow, double yellow, or green aspects, check the driver or warn him to regulate his speed according to whether the route over which he has to go is straight or diverging; then only one aspect at a time is required. A driver would not then be told over which route he is travelling; 2. locomotive engineers generally consider that the driver should be told the route which is set up for him to pass over : this can be done by two methods, *a*) providing at the junction a four-aspect colour light signal for each route, and erect them side by side, the signal aspects for the main route to be slightly higher than the signal for the left or right hand routes, or *b*) only one set of four-aspect signals with one route indicator above it.

In the case of *a*) the number of lights are increased, and a driver passes two or more lots of four-aspect colour light signals close together, whereas in the case of *b*) only one coloured light aspect is exhibited shewing the state of the road ahead and the route set up for the train to travel over is displayed on the route indicator above the aspect, by a brightly illuminated letter or figure.

It can of course be arranged in both cases *a*) and *b*) for the sequence of aspects displayed in the signals leading up to the junction to be double or single yellow or green, according to whether it is desired to warn or caution the drivers to get their trains under control, or to advise them the road is clear and straight for them to travel over the junction at speed.

A compromise has been arranged at Cannon Steet and Charing Cross, and at running junctions; the principle of *a*) is adopted and a four-aspect signal provided for each route, but at low speed junctions, such as trains starting from rest at a platform, or the home signal for entering the stations, route indicators have been installed, the idea being that the driver should be told the route over which he is to travel as far away as he can see the light signal itself.

It would appear sufficient if the driver were told by the colour light aspect the state of the road ahead at, say, 880 yards distant, and the route over which he was to travel about 150 to 200 yards away. The single aspect with the route indicator is by far the simplest to give the driver, and the simplification is an advantage. I consider that in the future, the signal aspect and the route indicator

will be generally adopted on account of their simplicity and economy in first cost and of maintenance.

The route indicator in use at Cannon Street consists of *a*) a plain lens, behind which when an indication is to be given is a disc on which the letter or figure is stencilled. In the focus of the lens is fitted a single focus 48-watt lamp. In front of the lens, a violet tinted glass screen, slightly etched, is fixed; the rays of light passing through the stencilled spaces forming the figure, are converted into nearly parallel rays by the lens as they pass through it and the rays impinging on the violet tinted glass screen give out a brilliantly illuminated letter or figure which can be seen distincly over a wide range to the left or right or underneath the signal.

During the day, a current of 4 amperes at 12 volts is supplied to the lamp, but during the night-time the letter is too brilliant at that voltage, therefore during the dark hours the voltage is cut down by means of a switch in the signal box to 6 volts, and the current approximately 2 amperes or 12 watts, the light given off being quite sufficient during the dark hours to give a brilliant indication.

In one case at Charing Cross, from Nos. 4-5 platform roads, the driver passes the platform starter and quickly comes to a signal for the converging road that is common for both roads, and which platform roads 4-5 converge into. It has been arranged by the use of a two-beam lamp that when the road is set for the driver from No. 4 road, that the light aspect shall be towards him, and so that the driver on No. 5 road shall not see it, and vice-versa. This is quite unique.

It has not been necessary to use any auxiliary or repeater aspect of signal, as the four-aspect colour light system avoids the necessity.

Table V will be of interest as it gives particulars of the number of relays and other apparatus used on the installation.

Only block bell working is in use over the whole of the area covered by the light signalling schemes that have been installed. Between Charing Cross and the next signal box Metropolitan junction, there are two automatic sections, but the trains are belled on to Charing Cross, and vice-versa. In addition, use is made of train describers to enable the signalmen to send the description of the train to the man in the next box, for route direction, and to give him time to set up the route desired by the time the train arrives at his box, if possible.

In consequence of the installation of these schemes in the Cannon Street and Charing Cross area, five signal boxes have been dispensed with, there having been seven under the semaphore system and only two under the new power and four-aspect colour light signalling scheme. There are two signal boxes on the Holborn to Elephant and Castle area; under the semaphore system of signalling there were 7. Therefore 5 have been dispensed with, making a total for the whole area of the four-aspect colour light signalling of 10 signal boxes dispensed with.

Between Charing Cross, Cannon Street, Metropolitan junction and Borough Market, the total number of levers is 321; previously, under the semaphore system, there were 795. At present there are 20 block sections; previously, there were 24. Paradoxical as it may appear, more trains can be run over the area owing to the four-aspect colour light signal system introduced, as the trains can run at higher speed.

The total number of incandescent electric lamps of all kind at Cannon Street and Charing Cross is 1 664, many lamps in the green and yellow aspects having lasted over 8 500 hours. The red aspect are changed after 750 hours.

As the clear and coloured lenses could not be obtained in England, all the clear, coloured and other lenses had to be procured from America, and very good lenses they were, but I am pleased to say that I have some clear and coloured step

TABLE V.

Number and particulars of apparatus.

Cannon Street and Charing Cross.

—	Charing Cross.	Cannon Street.	Metropolitan Junction.	Borough Market.	Waterloo.	Total.
Track circuits	60	70	26	13	18	187
Four-aspect light signals : vertical type	12	9	5	4	6	36
— — — cluster type	10	4	9	4	2	29
Three-aspect light signals	6	7	...	...	...	13
Two-aspect shunt signals	37	42	10	...	...	89
Total number of colour aspect units	198	178	76	32	32	516
Shunt signals preceeding running signals	5	8	...	...	...	13
Number of electric lamps in signals	249	188	122	64	64	687
Route indicators	8	15	4	...	...	27
Track circuit relays	43	70	23	13	16	165
Track repeater relays	52	47	22	4	...	125
Point detector relays	25	42	16	3	...	86
Point detector repeater relays	21	40	...	...	...	61
Signal relays	97	89	44	16	24	270
Signal stick relays	38	49	15	5	...	107
Approaching locking railways	10	25	7	...	...	42
Slot relays	...	3	6	3	...	12
Power signal frames	1	1	...	...	...	2
Number of levers	100	140	...	...	...	240
Spare levers	6	9	...	...	...	15
Mechanical frames	...	...	1	1	...	2
Number of levers	...	...	55	21	...	74
Spare levers	...	...	7	3	...	10
Number of electric lamps for indication on frames	272	293	...	..	...	565
Number of point power movements	46	68	...	..	...	114

or dioptric lenses which have been made in England by Messrs. Chance Bros., of Birmingham. I think this is the first time any English made coloured lenses of the kind and of such optical perfection have been publicly exhibited. I am pleased therefore to have the honour of being able to show them to any of you who wish to see, or are interested in them.

MISCELLANEOUS INFORMATION

[62. (01 & 625 .143.3]

1. — Corrugation studied at Montreal.

Figs. 1 to 4, pp. 1000 to 1002.

(*Electric Railway Journal.*)

In connection with the work of the committee on rail corrugation of the Canadian Electric Railway Association specimens of deeply corrugated rail were removed from service in Montreal, plan and profile drawings prepared from them, the corrugations photographed, observations on hardness made over the running face and microphotographs secured of cross sections at crests and valleys of the corrugated spots. This investigation was carried out by Gordon Sproule, M. Sc., assistant professor of metallurgy, McGill University.

Specimens examined were : *a*) parts of four transverse slices of a lipped rail, punch marked (.) (..) (...) (....), which had been cut alternately from the troughs and crests of the waves in a badly corrugated rail, and *b*) a length, about 40 inches, of the head of the rail. The slices, as may be seen from an accompanying illustration, showed the rail to be badly worn. The head was worn down until the wheel flanges ran on the lip, and in places the latter was stripped off.

The length of rail head had been cut off the web, presumably parallel to the base of the rail. It showed à very decided camber, being convex up, evidently due to the release of compression stresses in the wearing surface, developed by the rolling and pounding of the wheels. According to the report, this circumstance suggests a feature in the manufacture of rails which may be worthy of consideration in connection with corrugation.

Rails, when they are rolled, are given a definite camber (head convex) when hot, because, as they come from the rolls, the lighter base and web are at a lower temperature than the heavier head, and the camber counteracts the greater shrinkage of the head as the rail cools, so that the rail is straight when cool. No doubt the temperature variations and amount of camber required are occasionally misjudged, resulting in rails that have a camber after becoming cool and necessitating a straightening operation. It would seem highly desirable that specifications for tramway rails require that such straightening be done in rolls and not step by step in a press.

The specimen selected was badly corrugated, showing in the 40 inches three distinct hills (or crests), a double hill or plateau and four vales (or troughs). Besides the visual examination, the head and cross-sections of the rail were tested for hardness and examined microscopically.

Brinell impressions were made approximately along the center line of the wearing surface of the 40-inch length of head, spaced a little more than 1 inch apart; 31 impressions were made in 38 inches. The figures are given in an accompanying table. A distinct and consistent relation is apparent between the hardness and the hills and vales of the corrugations. It is obvious, the report states, that the corrugations are not the result of varying hardness, but that the varying hardness is the result of the corrugations.

At first sight it might seem probable that the rising side of the hills would be the harder, but the specimen is a left-hand rail and the falling side of the hills is consistently the harder, except at the so-called plateau. These facts suggest further study to see how the severity of the corrugations is related to the irregularity of spacing and how the hardness relation varies with the irregular wave spacing.

Brinell hardness readings along center line, top of head.

Position.	Hardness.	Remarks.	Position.	Hardness.	Remarks.
1	271	...	17	244	...
2	269	...	18	262	...
3	255	...	19	269	Vale.
4	248	Hill.	20	269	...
5	255	...	21	255	...
6	264	...	22	243	Hill.
7	269	Vale.	23	254	...
8	269	...	24	253	Plateau.
9	255	...	25	255	...
10	255	Hill.	26	255	Hill.
11	255	...	27	263	...
12	255	Vale.	28	277	...
13	269	...	29	269	...
14	269	...	30	269	Vale.
15	255	...	31	255	...
16	241	Hill.			

Even lacking this information, there would seem to be no doubt that the frequency of the waves, which are equally spaced, in the specimen rail, as they were encountered by wheels of cars moving at the average speed for the location, synchronized with the natural period of vibration of the wheels and axles, as governed by their weight and the character of the spring gear. This synchronism would be only slightly affected by the natural period of the rail and its foundation, and the pounding effect would be aggravated by a solid foundation. This argument points to advantages : 1. in heavy wheels and axles and flexible spring gear, resulting in a low frequency vibration, longer waves, and easier riding cars, and 2. in designing several different truck constructions, so that an incipiently corrugated rail might be as little as possible subjected to synchronous pounding of one common frequency. In any

Fig. 1. — Four transverse slices taken for examination from a piece of badly corrugated rail in Montreal, the first and third being from the troughs and the second and fourth from the crests of the waves.

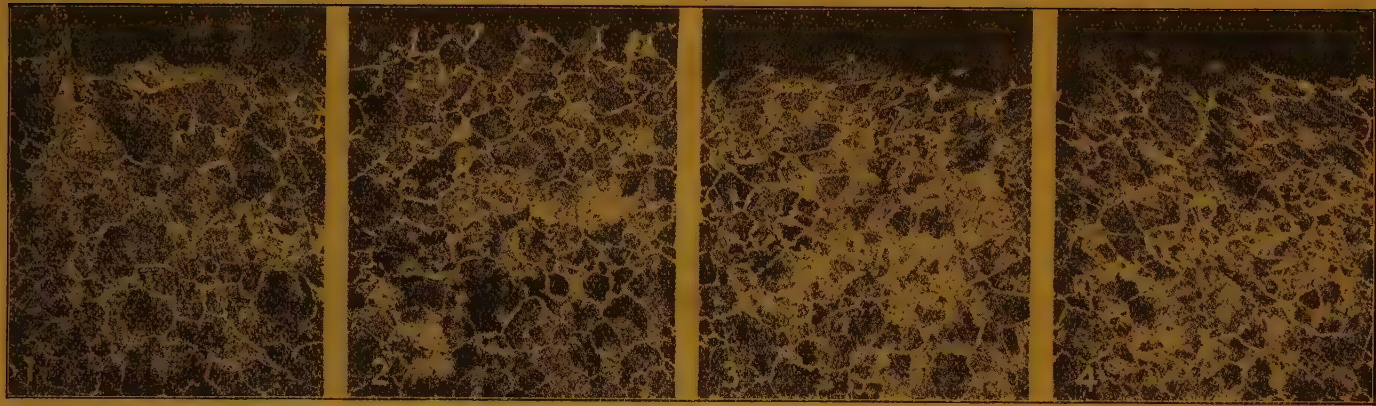


Fig. 2. — The appearance of the slices after surfacing and etching was much the same for all four specimens.

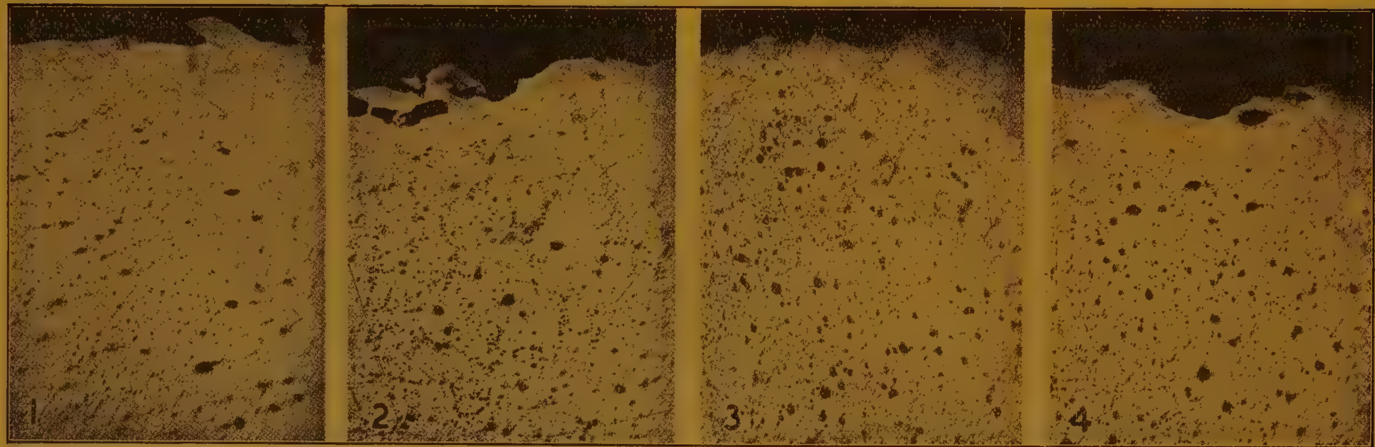


Fig. 3. — Microscopic views at enlargement of 75 diameters show the varying porosity of the metal.

case, probably the waves gradually move along the rail as wear proceeds, and their final position bears no relation to the position of any original crest or hard or soft spot that started the growth of corrugation.

Brinell hardness tests were also made of the slices, at a central level in the head, nearly above the web, as shown in an accompanying sketch, with the following results :

Slice number.	1	2	3	4
Brinell number . . .	251	255	248	241

This interior hardness is about the same as that of the hills, and, of course, shows much less variation than the surface hardness readings. The Brinell tests show the steel to be very hard.

The four transverse slices were surfaced by hand and deeply etched. They were photographed in pairs to make comparison easier and are shown in accompanying pictures. As may be seen from the illustrations, no great differences of structure were apparent; the steel is reasonably uniform throughout the section and from section to section. The flow lines produced in rolling are indicated, in the region where the head and web join, by segregated constituents, and traces of a rim of blowholes show in the outer part of the head.

A sample was cut from each of the four transverse slices, in the position shown in the sketch. The effects of the previous deep etching were ground out and the same cross-sectional faces of the samples were polished

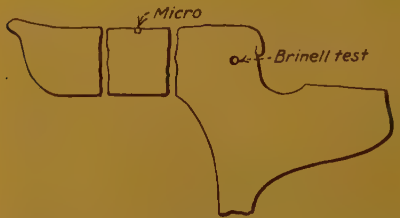


Fig. 4. — Location of Brinell tests and microscopic examinations.

for microscopic examination. An area, including the edge of the top surface, as shown in the sketch, was photographed in the plain polished condition to show the soundness or porosity of the metal. These are reproduced herewith. All micrographs were made at a magnification of 75 diameters. While photographs made under these conditions are apt to be misleading because the appearance produced depends a great deal on the technique of polishing and photographing through the exaggeration of very minute pores, it may be said that the size and number of the larger pores are about the same in each slice; No. 1 was evidently less eroded in the polishing and Nos. 2 and 3 more so than No 4.

The photographs show very high carbon steel, probably between 0.7 % and 0.8 % C., in the slowly cooled condition; this agrees with the Brinell hardness figures obtained. The grain size is medium and the same from section to section, as would be expected.

An interesting thing is the visible result of the coldwork pounding and dragging done on the rail by the wheels. This is quite evident, although the sections are transverse and not longitudinal and although an appreciable amount of the surface metal was removed in the previous deep etching. The deep etching also accounts for the jagged appearance of the edge. In samples 1 and 4 the effect is visible to a depth of about 1/50 inch and is away from the lip of the rail. In sample 2 there is no sign of the cold-work. This agrees with the fact that 2 was cut at a hill-crest and that the crests are soft compared with the vales. Why No. 4, which was also from a crest, shows so distinctly the cold-work effect cannot be explained, but it may be pointed out that its head thickness is considerably *less* than that of 3, said to be from the adjacent vale. In sample 3 the apparent depth of the cold-work effect is less than in 1 and 4, agreeing with the greater head thickness, and the dragging effect seems to be in the opposite direction to that in 1 and 4, namely toward the lip of the rail.

Under the microscope the lower, unworn side of the head is seen to have a layer of considerable thickness of partly decarburized metal. The amount and uniformity of this layer on the original wearing surface would no doubt be a factor in the tendency of the surface to develop waves.

Preliminary conclusions drawn from this in-

vestigation are : 1. The rail should be rolled straight and not kinked by « gagging »; 2. The character of the original surface, as regards uniformity of hardness and soundness, would be a factor in the starting of waves; 3. The internal structure probably has no effect — the present very badly corrugated rail is very hard and uniform. A rim of sub-surface blowholes might have some effect, but the surface conditions would be the main factor, as stated in 1 and 2. Thus, while sound steel is in general preferable to rimming steel, a more direct benefit would be incurred by the use of the Lackawanna « de-seaming » process — if it is still in use — than by insistence on dead-setting sound steel; 4. Synchronized pounding of the wheels would seem to be a most important factor. Efforts might be made to reduce and to vary the frequency of the natural period of wheels and axles.

[625 .143.3 (.73)]

2. — Stress in rails has important bearing on failures.

Figs. 5 to 7, p. 1004.

(*Railway Age.*)

An interesting and informative study of rail failures has been made by the Pittsburgh & Lake Erie Railroad which indicates clearly that there is an intimate relation between the strength and stiffness of the track structure and the loads imposed upon it. The essence of this study, which extends back to about 1915, is illustrated in the chart which shows the relation that has existed on that road between the weight of the track rail and that of the rolling stock, and, also, the relation of these two factors to rail failures.

History of the rail failures.

From 1910 to 1916 the track on the Pittsburgh & Lake Erie included several sections of rail, the heaviest of which was the 100-lb. A. R. A.-B. section which was standard for main line tracks. During the same period the heaviest power used on the road was the *Consolidation* or 2-8-0 type with axle loads of about 42 500 lb. With this track and motive power, the number of rail failures ranged from about 170 to 220 yearly until 1915, when, owing to the gradual decrease in the mileage of light rail, the number of failures dropped to about 85. With the continued increase in the amount of 100-lb. A. R. A.-B. rail in service to about 72 000 tons, or 100 % of the total in main tracks, and with little change in the rolling stock, the number of rail failures declined still further until 1918, when its minimum was about 65.

Apparently, within this latter period from 1915 to 1918, a relation existed between the weight of the rail in the track and the weight of the rolling stock which was conducive to the development of few rail failures, for when this relation was altered materially during the next three years by the rapid increase in the weight of cars and power, while the track structure remained about the same, the number of failures increased rapidly. In analyzing this situation it is noted that during 1916 the Pittsburgh & Lake Erie began to introduce locomotives of the *Mikado* 2-8-2 type with axle loads ranging from 60 000 to 75 000 lb., and almost concurrently began to purchase cars of 70-ton capacity with loaded axle loads of about 51 000 lb. until 1918, when there were only about 35 of the heavier locomotives and about 2 000 of the larger cars in service, their effect upon the rail was not appreciable, but when in 1919 the number of these locomotives had increased to 65 and the number of 70-ton cars to 2 500, the number of rail failures immediately increased from the earlier minimum of 65 to about 200. Even more striking was the increase in the rail failures which occurred during the following year under practically the same conditions of track and loads, when the number mounted to about 700.

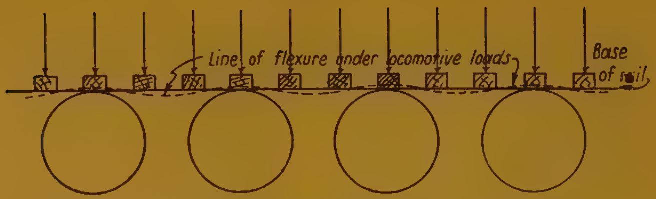


Fig. 5. — In reality the rail is a continuous beam supporting the reactions of the roadbed.

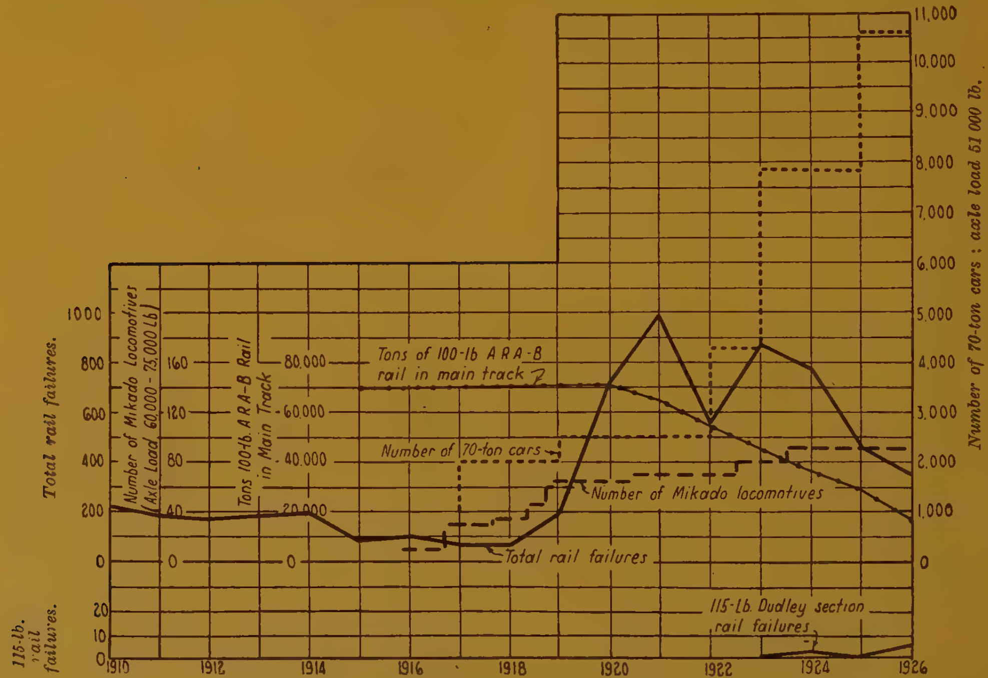


Fig. 6. — Chart showing the relation of rail and axle loads to rail failures on the main tracks of the Pittsburgh & Lake Erie.

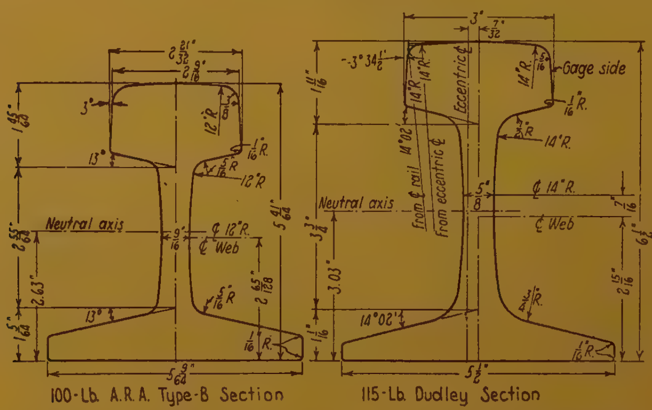


Fig. 7. — Details of the 100-lb. A. R. A. type B section and the 115-lb. Dudley section.

Analyzing failures leads to more rigid rail.

Apparently the 100-lb. A. R. A. rail with its relatively thick head and shallow web was not capa... carrying the increased loads, so in 1921 the Pitt... & Lake Erie began to replace this rail with 115-lb. Dudley section rail, in which an attempt made to secure increased strength, but more particularly a large increase in girder strength and stiffness. These characteristics were found in the new section, where a reapportionment of the metal gave the rail a relatively smaller head and base but a considerably greater over-all depth and fishing distance. The effectiveness of the new section in affording increased rigidity is evidenced by the fact that with only 15 % more metal it provides approximately 50 % greater stiffness.

The reason for desiring rail of greater stiffness is apparent from a study of the action of rail under moving loads, in which it can be assumed to approximate a continuous beam with continually varying points of support and so subject to a continual reversal of stresses. This situation is shown in the sketch where the ordinary relation of the locomotive drivers to the rails has been reversed to indicate more clearly the actual conditions that exist with respect to loads and reactions on the rail. Here the locomotive drivers, with 60-inch spacing, are shown to support the varying reactions of the roadbed, the dotted line indicating the continuous girder effect of true line of flexure which obtains in the rail. To reduce this wave motion in the rail and the constant reversal of stresses set up by it, and furthermore, to minimize the flexibility of the rails at joints which had been causing the destruction of both the rail ends and the splice bars in spite of a high standard of maintenance, the high Dudley section with correspondingly high rigid splice bars was adopted.

Going back to the original chart and the serious situation that existed with regard to rail failures in 1920, it is seen that with the release of about 7 000 tons of the old 100-lb. rails during 1921, there was an appreciable decrease in the increased number of rail failures during that year, in spite of the fact that the total number of failures reached the unprecedented peak of about 980. During the following year, with the release of about 10 000 additional tons of the old rail and with little change in loadings, there was a rapid decrease in the number of failures, the total number being only 550, or 430 less than in the preceding year. In 1923, the addition of about 1 750 of the 70-ton cars and the gradual increase in the number of *Mikado* locomotives in operation, which reached a total of 80, again disturbed the trend of failures and in spite of the further removal of the 100-lb. rail in service, the number of rail failures increased to 860.

Since 1923, a more favorable situation has obtained with regard to the number of failures which have occurred yearly, there having been 770 in 1924, 450 in 1925, and a further decrease to 350 in 1926. These marked reductions in the number of rail failures have occurred although the number of 70-ton cars in service increased to 10 600 in 1926, and the number of *Mikado* locomotives to a total of 91. Accompanying this large increase in loadings, however, has been the continual decrease in the amount of old 100-lb. rail in main tracks, until the rail of this section remaining at the end of 1926 amounted to only 16 000 tons, or about 22 % of the amount in service in 1920.

From the foregoing it is evident, therefore, that the solution of the rail failure problem on the Pittsburgh & Lake Erie is being effected through the building up of a track structure such that its relation to the heavier loading will more nearly approach the situation prevailing from 1915 to 1918, which was conducive to a minimum number of rail failures. That such a condition will undoubtedly be realized within the next few years as the remaining old light rail is replaced by 115-lb. Dudley rail is evidenced by the fact, as shown in the chart, that during the past three years when the amount of 115-lb. rail in service greatly exceeded that of the old 100-lb. section, there was a total of only 11 failures in the heavier section as compared with a total of about 1 570 failures in the much smaller amount of the lighter rails.

While the reduction in rail failures has been

the particular end sought in the adoption of the 115-lb. rail on the Pittsburgh & Lake Erie, it is interesting to note the effect that the heavier rail section with its more rigid splice bars has had on joint maintenance. With the 100-lb. rail and its shallow 26 inch heat-treated bars, the flexibility of the joints under moving wheel loads was so great that the horizontal component of the vertical stresses caused bars and ficient abrasive action between wear them down, the rail heads and bars to come in contact with permitting of the rails within about three years. When this condition had been reached it was found that regardless of the use of joint springs or nutlocks, and continual maintenance, it was impossible to keep the joints tight. On the other hand, with the high 115-lb, rail, which has about 50 % greater stiffness, and with splice 38-inch corresponding stiff, heat-treated the wave bars in use, it has been found the horizontal com- motion at the joints have been so reduced that it ponent ... to maintain tight joints with less maintenance and without the use of spring washers of any kind.

This study of the rail failure situation on the Pittsburgh & Lake Erie has been carried out under the district supervision of A. R. Raymer, assistant vice-president and chief engineer of that road, to whom we are indebted for the information presented above.

[**624** .8 (.73)]

3. — A lift span of unusual design.

Figs. 8 to 11, p. 1008.

(From the *Railway Age.*)

In rebuilding a bridge over the White river at De Valls Bluff, Ark., the Chicago, Rock Island & Pacific Railroad replaced an old swing span with one of a vertical lift type that embraces a number of distinctive departures from current practice in movable bridges of this character. Among the unique features of the design is the elimination of independent haulage lines for lifting and lowering the span, movement being accomplished, as in elevators, by a direct motor drive to the counterweight sheaves. This arrangement calls for separate power units on each tower and introduces the possibility of unequal travel of the two ends of the span, a contingency which has been met in an effective manner in the arrangement of the control apparatus. The train of equalizer beams usually provided at one end of each group of counterweight ropes has been supplanted by hydraulic equalizers, by means of which all ropes were subjected to equal tension before the bridge was placed in service. Longitudinal struts near the top of the towers have been designed to serve as girders of adequate strength to carry the full load of the counterweights so that loose I-beams stored on these struts (clear of the counterweight travel) may be slid into position to carry the counterweight at any time that it is necessary to facilitate maintenance operations requiring the load to be released from the counterweight ropes.

The replacement project was the result of inadequacy and obsolescence of the old structure, of which the piers date back to 1870 when the Memphis & Little Rock Railroad, now a part of the Rock Island, was completed by the construction of a bridge across the White river. The original Howe trusses were replaced in 1899 by pin-connected through spans. As thus rebuilt, the old bridge consisted, from east to west, of a swing span 219 ft. 7 1/2 in. long and three fixed spans of 146 ft. 4 in., 147 ft. 11 in., and 150 ft. 2 in., respectively, on the original stone masonry piers. This structure was flanked on the east by 92 panels of ballast deck creosoted pile trestle and on the west by 52 panels of the same construction. This old bridge, as well as the one which now replaces it, were built to carry a single track.

Why the bridge was rebuilt.

While the old superstructure was of limited capacity as compared with present day requirements, the primary consideration leading to replacement was the failure of the old piers through the cracking of the bridge seats and the masonry immediately below them and instability resulting from disintegration of the cofferdams supporting the rock fill on which the piers rested. Piers 4 and 5 under the fixed spans were rebuilt first, and later, when it was found necessary to renew pier 3, which supports the west end of the old draw span and the east end of the adjacent fixed span, it was decided to replace the draw span. Negotiations with the United States War Department for authority to rebuild the bridge led to the approval of a plan for a vertical lift span affording a clear waterway opening of 175 feet between faces of supporting piers with a clear lift of 55 feet above high water. This required the construction of a span 182 ft. 4 in. long center to center of end bearings and with a vertical lift of 55 feet, with new flanking spans 147 ft. 3 in. long to carry the necessary towers. This plan, therefore, provided for the entire replacement of the old draw span and the fixed span to the west of it, as well as a portion of the approach trestle to the east of it. The change in the span arrangement necessitated the construction of piers at new locations under the east end of the new lift span and at the east end of the east fixed span. The work carried out under this plan was completed on 15 January 1927, and it is proposed to replace the two remaining old spans within a short time.

The new spans are through riveted trusses of the subdivided Warren type, the fixed span having 12 sub-panels 12 ft. 3 1/4 in. long and the lift span 16 sub-panels 11 ft. 4 3/4 in. long. The trusses are 18 ft. 6 in. center to center and the bottom and top chords are 33 feet center to center. The fixed spans have creosoted timber ballasted floors and the lift span a standard open floor. The end floor beams of all three spans are designed as lifting girders by means of which the spans may be lifted clear of their bearings on jacks if necessary.

Each corner of the lift span is suspended by means of eight Monitor steel ropes, 1 5/8 inches in diameter, furnished by the American Steel & Wire Company, Chicago. These ropes are carried up over cast steel sheaves 11 feet in diameter to connections with counterweights consisting of structural steel boxes filled with concrete. The weight of each counterweight is 361 470 lb. or one half the weight of the movable span complete.

Hydraulic equalizers.

To effect a connection with the counterweight, the eight ropes at each corner terminate in socket clevises which are connected by means of pins to piston rods that pass through eight cylindrical openings cast in a steel box 3 ft. 6 in. long, 2 feet wide and 1 ft. 4 in. high. Cylinder heads bolted to the cylinder block, together with packing glands for the piston rods where they pass through the cylinders at the top and bottom, provide a pressure tight construction. The bottom of each piston rod is threaded to receive two nuts which can be turned up to bear on a cast steel hood that covers the lower end of the cylinder. The upper end of the piston rods are stayed against lateral deflection due to angularity in the direction of the cables by means of spacing plates with slotted holes. Steel plates 22 inches wide by 3/4 inch thick, providing a connection between the cylinder blocks and a short equalizer beam, which is in turn connected to the counterweight hangers by a 4-inch pin, complete the connection between the counterweight ropes and the counterweight.

After the entire counterweight system had been assembled and the nuts on the piston rods had been turned up tight, pressure was applied to the tops of the pistons by means of a light oil thinned with kerosene delivered through 1/4-inch feed lines from a high pressure pump, Falsework under the counterweight was then removed and pressure increased until all of the nuts on the piston rods were loose. Then with the pressure maintained, all nuts were turned up to a snug bearing, thus holding each rope to the uniform tension set up by the hydraulic pressure.

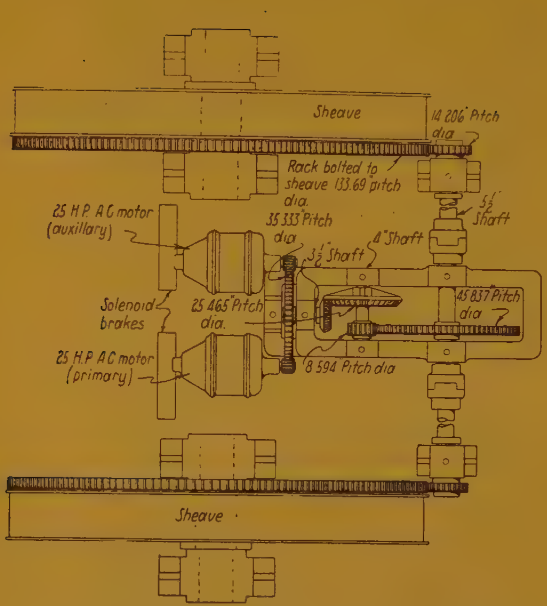


Fig. 8. — Arrangement of the direct motor drive to the counterweight sheaves at the top of each tower.

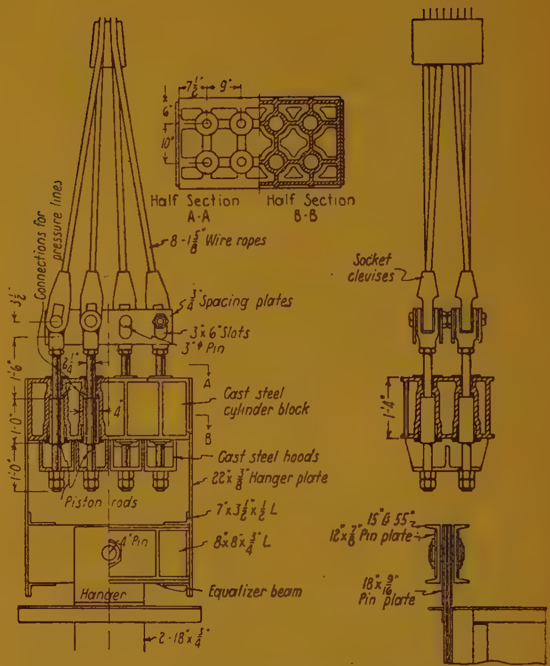


Fig. 10. — Details of the equalizer device provided at each end of the counterweights.

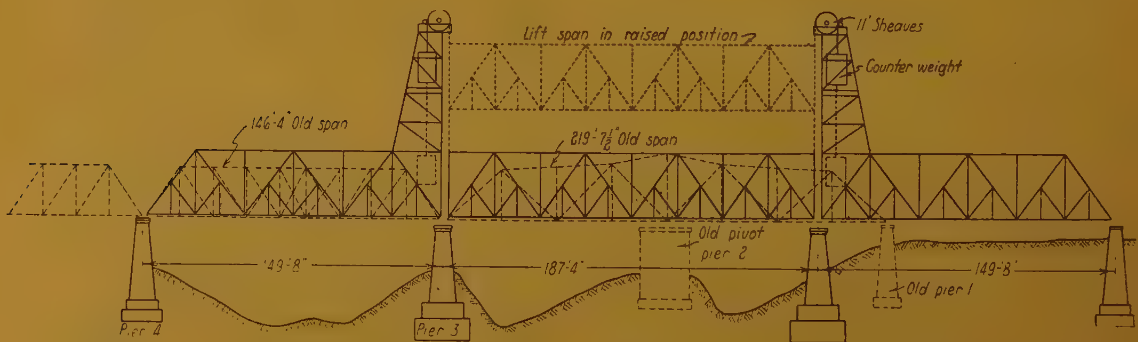


Fig. 9. — The new superstructure of the White river bridge in relation to the spans it replaced.

LEGEND : New spans ————— ; Old spans - - - - - - - - - -

Direct motor drive on sheaves.

Bolted to one side of each of the counterweight sheaves is a segmental geared rack which meshes with a pinion gear that is connected in turn through a train of gears to two 25-H. P. alternating currents motors, so arranged that the machinery may be operated by either one or both of the motors. Each motor is equipped with a solenoid brake mounted on an extension of the motor shaft. The motors as well as the brakes are subject to control from an operator's house located outside the trusses at one end of the lift span and by a limit switch operated by a worm gear from the pinion shaft.

Stopping of the movement of the span at the top and bottom of the vertical travel is cushioned by means of air buffers, those on the piers which receive the span in its down travel being 2 ft. 9 3/4 in. long by 10 inches in diameter and those at the top of the towers to cushion the upward movement are 2 ft. 8 in. long by 9 inches diameter. A beveled tongue type of bridge lock is provided on the bottom of each end floor beam to center the span as it closes by entering a slot in a casting mounted on each bridge seat. The rail lock is of the easer tongue type. The tongue comprises a projection of a steel casting bolted to the ties on the movable span and extending out onto the fixed span where it seats in a slot formed in a casting attached to the ties of the fixed spans. A plunger lock insures that positive alinement is obtained before the signals can be lined up to move trains across the bridge.

Movements of trains across the bridge are controlled by an electric interlocking plant operated from a deck lever type controller in the operator's house. No derails or smashboards are used, but home and distant color-light signals are provided for movements in both directions. One lever controls the circuit breaker for power to operate the bridge so that the signals must all be at the stop indication before the bridge can be opened. Similarly, when the bridge is closed the bridge locks and rail locks must be in correct position before the signals can be set to indicate proceed.

How the operation is controlled.

Power for the operation of the bridge is taken from a 13 000-volt power line of the Arkansas Light & Power Company and is delivered to the motors as 440-volt, 3-phase, 60-cycle current. The bridge operating control equipment includes a master controller, a leveling controller, a brake controller, a selector controller for each of the four motors, and a foot release. The indicating equipment consists of a board equipped with a dial having a pointer showing the relative elevations of the two ends of the span and five jewel type lights arranged as follows : Two lights at the bottom which show white when both ends of the bridge are down; a light above these which shows red when the bridge is nearly down, a second light which shows red when the bridge is nearly open, and a top light which shows green when the span is fully open.

To raise the span, the following sequence of operations is carried out : The interlocking signals are set at stop, thus making power available for the opening of the bridge. The brake controller is set in the release position. Two of the motor selector controllers are set in the on-position, that is, one for a motor at each end of the bridge. Following this the handle for the master controller is moved progressively through the eight points to release the brakes and accelerate the motors to full speed. With the bridge in motion, the operator places his hand on the handle of the leveling controller and watches the level indicator to check any tendency for one end of the span to travel faster to the other, in which event he moves the handle to the right or the left as the case may be, to retard the speed of the motor on one tower or the other.

Limit switches cut power off.

A similar sequence is carried out in lowering the span. When the span reaches a point 3 feet from the upper or lower limits of its travel, the limit switches cut off power, stopping the motors and setting the brakes. To complete movement, the operator must return

the handle of the master controller to off-position, following which he may make use of the foot release to regain use of the controller, but this operation gives him only the first four points of acceleration so that the movement to fully open or fully closed positions is at slow speed.

Failure to keep the two ends of the span level, with a resulting excess in the relative elevation of one end over the other, also results in an automatic shut-off of power which is again made available under limitations as explained above.

The construction of the new piers, particularly the replacing of the old piers, was attended by much difficulty, because it was necessary to support the spans on falsework while the old piers were removed and the new ones were built. To do this it was necessary to carry the ends of the bridge spans on girders spanning longitudinally between bents driven on each side of the old pier. In order to put these girders into position it was necessary to cut notches through the top of the piers, an operation which had to be carried out with extreme care because of the shattered condition of the upper portion of the pier masonry. A detailed account of the manner in which this work was handled on two of the piers was given in an article appearing in the *Railway Review* of 26 August 1923, page 259. The removal of the old steel and the erection of the new was carried out on falsework in accordance with commonly accepted practice. The substructure work was done by the Bates & Rogers Construction Company of Chicago. The structural steel and operating machinery were fabricated by the American Bridge Company, and erected by the Kansas City Bridge Company, with the exception of the control and electrical equipment which was installed by the American Bridge Company. The design and construction of the bridge was under the direction of I. L. Simmons, bridge engineer, Chicago, Rock Island & Pacific, and under the general supervision of C. A. Morse, chief engineer. S. T. Corey, assistant bridge engineer, supervised the design and Bert Matheis, chief bridge inspector of the railroad, supervised the construction.

[625 142.4 (01 (.73)]

4. — Pennsylvania Railroad starts extensive tests of concrete ties.

Figs. 11 to 13, pp. 1012 and 1013.

(*Railway Engineering and Maintenance.*)

Twenty-five years of sporadic endeavor to develop a concrete substitute for the wooden cross tie have been attended with indifferent success. Whether this has been due to improper design, poor workmanship, excessive cost or lack of interest on the part of railway officers need not be discussed here. The installation of the various designs of ties have been made with a relatively small number of ties, usually in unimportant tracks, and have received little attention. In fact, if it had not been for the efforts of the sub-committee on substitute ties of the American Railway Engineering Association, little or no record would be available today of the varied designs that have been tried at different times during the first quarter of the present century.

In view of this, it is of particular interest that the Pennsylvania Railroad is now installing several thousand reinforced concrete ties in the Eastern and Central regions for the purpose of conducting what is without question the first conscientious attempt made by any American railway to determine the possibilities of concrete for this purpose. Preliminary installations of ties of the same general design as those now being delivered to the railroad were made on the Streets Run bridge near Pittsburgh, Pa., and at Aspinwall. Both of these installations are in main tracks of the Pittsburgh and Connaught divisions of the Pennsylvania and were placed in October and November 1925, respectively.

Present plans call for the use of these ties

in about three miles of main line freight tracks between Pittsburgh and Philadelphia, while a number will be used in main tracks of branch lines. The ties are being manufactured for the Concrete Tie Company, Pittsburgh, Pa., and furnished to the railroad company on contract.

The tie which is now being installed does not differ greatly as to size and shape from the standard wooden tie. It is 8 feet long, 10 inches wide and 8 inches high, except that the ends are raised for a length of about 11 inches to provide a shoulder to receive the thrust of creosoted oak blocks 14 inches long, 5 inches wide and 1 3/4 inches thick which serve as rail seats. Two octagonal holes pass through the tie at the rail seat to receive 3-inch creosoted oak spiking plugs.

No change in the customary rail fastening is involved in the design, except that longer spikes are used to make up for the thickness of wooden tie blocks and to provide sufficient penetration into the spiking plugs. The tie plate differs from those used on wooden ties in that it is shortened somewhat in length and the edges are rolled down so as to compress the wooden tie blocks. This makes up to a certain extent for the reduced bearing area under the rail as compared with the full width of a wooden tie. These tie plates weigh 11 1/2 lb. each and the steel reinforcement for one tie weighs about 57 lb.

The design.

The tie is designed to carry a locomotive wheel load of 127 000 lb. (including the impact allowance). This load is assumed to be distributed over three ties, making a total load of 42 400 lb. for each tie. The roadbed reaction is assumed as uniformly distributed over the entire length of the tie, amounting to 5 300 lb. per linear foot of tie. These assumptions as to loading produce theoretical stresses of approximately 1 100 lb. per square inch compression in the concrete, 17 000 lb. per square inch in the tensile steel and about 7 000 lb. per square inch in the compression steel. The unit shearing stress in the concrete under the rail is approximately 250 lb. per square inch. The assumed loading is approximately equal to that produced by a Cooper E-60 locomotive with an allowance of 100 % for impact.

In addition to the longitudinal and web reinforcement, the ties are provided with spirals with an inside diameter of 5 1/4 inches made of 1/4-inch diameter rods on a 1-inch pitch which are installed around each spiking plug to increase the spike-holding power and to resist bursting pressure occasioned by driving the spike plug or swelling of the plug with the absorption of moisture.

The design of the ties used on the Streets Run bridge and at Aspinwall is somewhat different from that of the ties now being manufactured. The diagonal or shear reinforcement connecting the top and bottom longitudinal bars was not present in the first design. The central bar was also absent and some cracks opened up in the first installation due to center binding. Tests on the design now used were made as a result of the experience on the first installation which show that the present ties will carry a load applied at the center of the tie when simply supported upside down along the line of the rail bearing to the amount of 32 800 lb. This corresponds with the load capacity of 20 000 lb. for the ties that did not have the shear reinforcement or the extra bar in the top.

The ties are being manufactured by the John F. Casey Company, contractors, Pittsburgh, Pa., at a plant in Aspinwall. The molds for the ties are of the gang type and each gang consists of approximately 100 molds. The bottom of the molds consists of a plank platform raised about two feet from the earth floor of the building. The side forms or dividing plates are of steel and the end forms consist of wooden blocks. The ties are cast bottom side up. While the concrete is being placed the assembled « cages » of reinforcement are jiggled and the concrete worked into the molds by hand so as to secure thorough embedment of the bars.

Finishing is done with a handled wooden float immediately after which the entire gang of filled forms is covered with tarpaulins carried on a framework. The sides of the tarpaulin hang down to the floor enclosing the entire set of molds and steam is turned into

Fig. 11. — Concrete ties on the Streets Run bridge, Monongahela division : In the insert, a phantom view showing the reinforcement.

Fig. 13. — Making the ties. One rack of forms partly poured, one rack with the reinforcement in place and one rack being cured by steam.

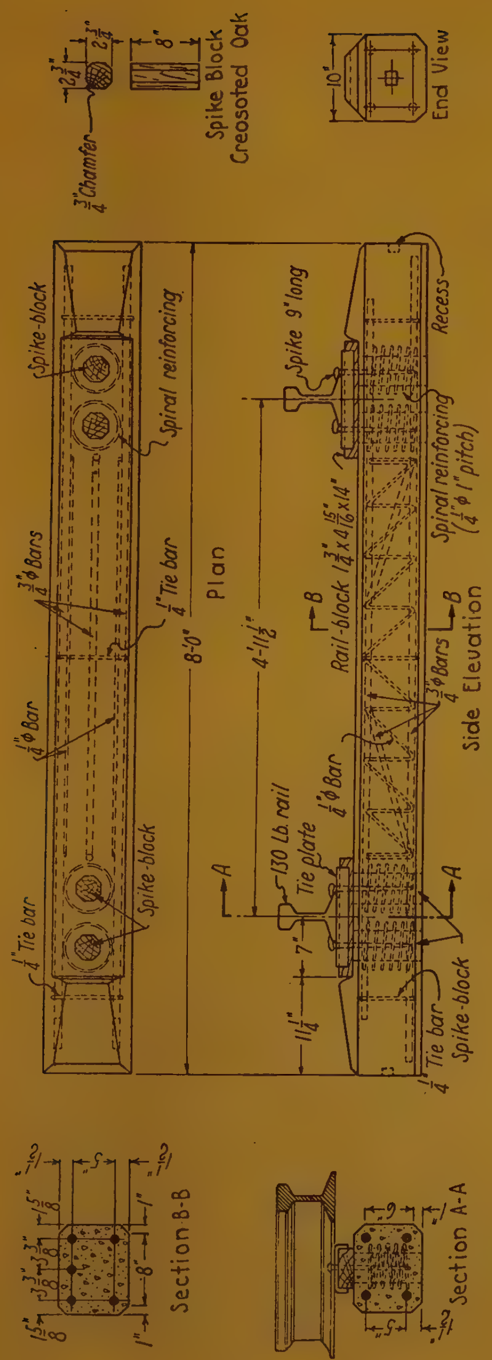


Fig. 12. — Details of the reinforced concrete tie.

the space under the tarpaulins through perforated steam pipes laid along the ground at each side of the platform. This « steam curing » is carried on for 24 hours, after which the ties are exposed to the air of the plant for another 24 hours and then handled in groups by a five-ton overhead crane to cars for shipment. Thus the ties are shipped out of the plant 48 hours after casting.

The mix was worked out to produce concrete of 2 500 lb. per square inch at 28 days with approximately a four-inch slump and consists of one part cement, 1.8 parts sand and 2.4 parts gravel. The aggregate is obtained from the Allegheny river. Test cylinders show that at 48 hours after curing the concrete has attained a compressive strength from 900 to 1 100 lb. per square inch.

Details of manufacture.

The mixer is a batch type of 1/2 cubic yard capacity. The water is regulated by means of a tank equipped with a gage and a graduated scale, by means of which the amount of water used for each batch is easily controlled. The aggregate is supplied to the mixer from overhead bins and is measured in mechanical batchers.

The concrete is handled from the mixer by means of a five-ton overhead crane. The mixer dumps directly into truncated cone-shaped buckets that are handled by the crane to proper place over the gang molds. In fact, all of the heavy work in the plant is done by this overhead crane.

Not only are all of the bars bent in the assembly room, but the wooden plugs are manufactured there also. The lumber for these plugs consists of three-inch oak planks which are first ripped into blocks 3 inches square and then passed through a four-side sticker, thus producing pieces roughly octagonal. These pieces are then cut by a power saw to the required size and, after drying in a rack over a coke salamander, are dipped in creosote.

The capacity of the plant including the assembling of the reinforcement, manufacture of plugs, placing of concrete and removal of the completed ties, is about 150 ties per day. The plant is operated by about 30 men.

The work of manufacturing the ties was in progress during the past winter and, in order to make it possible to ship ties in 48 hours, the water was heated to about 150° F. and the aggregate also heated by means of steam coils in the overhead bins. The concrete was placed at a temperature of about 70° F. and as soon as covered with tarpaulins the temperature was raised by means of live steam to about 90°. After each use the forms are cleaned by brushing and scraping and oiled with Corvus form oil.

Installation and handling.

Since these ties weigh approximately 600 lb., mechanical equipment for unloading and handling them is desirable. Unloading has been efficiently done with an ordinary air-hoist rail unloader. It is expected that similar equipment will be used to distribute the ties and that installation in face will be handled by power equipment. However, the tie is of such weight that it can be handled by five or six men.

The economic advantage of these ties as compared with wooden ties cannot be definitely determined at the present time. The installation on the Streets Run bridge has indicated that the track holds its line and surface on the concrete tie section much better than it does on the wooden tie tracks adjoining. This is probably due to more bearing on the ballast afforded by the concrete tie and to its greater weight. Estimates based on reasonable assumptions as to service life and cost in place indicate that at the present there it little difference in annual cost. Such estimates do not, however, give effect to better track condition and reduced track labor. It may be that these factors will make the concrete tie decidedly more economical than the creosoted wooden ties.

Much of the data for this article was furnished by the Concrete Tie Company of Pittsburg. A. C. Shand, formerly chief engineer and now assistant to the vice-president of the Pennsylvania, was largely responsible for the decision to install these ties in tracks of that road.

[625 .235 (.73)]

5. — The Frisco's experience with lacquer,

By H. L. WORMAN,

SUPERINTENDENT MOTIVE POWER, ST. LOUIS-SAN FRANCISCO, SPRINGFIELD, MO.

(From the *Railway Age.*)

Since November 1924, the St. Louis-San Francisco has applied the lacquer finish known as Duco to 274 passenger cars of both steel and wood construction, to 626 locomotives in all classes of service and, within the past six months, to 30 passenger car interiors. The results on steel equipment have been satisfactory, demonstrating marked advantages over former finishes in speed of application, durability under adverse climatic conditions, attractive appearance which improves after repeated cleaning, and other operating advantages. While wooden cars have always presented a more difficult problem of painting than steel cars, from the standpoint of the durability of the finish, and some early experiences with lacquer on wooden cars of the St. Louis-San Francisco were unsatisfactory, a flexible lacquer, designed especially for wooden interiors and exteriors, has now been in service for about a year with good results.

The quick-drying feature of lacquer, together with its rapid application usually by means of a spray gun, greatly reduces the time which equipment must spend in the paint shop, and experience on the Frisco has shown that this time, as compared with that necessary with the common varnish system, is approximately 50 % less. The saving in time is offset to a certain extent by greater material cost, but this leaves a large net economy due to greater durability of the lacquer finish, easier cleaning and other factors. While varnished Frisco cars formerly had to be refinished on an average of every 18 months, 274 of these cars, sprayed with Duco, in most cases over the old undercoats,

have now been in service up to 30 months with no attention except cleaning and they show no indication that refinishing will be necessary until after a still further extended period of service.

Locomotives finished with varnish are in service an average of 12 to 18 months before the finish needs renewal, but the average service life with Duco finish on a locomotive is increased to 18 to 24 months and the labor cost of application is 30 % less. It is easier to clean cars or locomotives finished in lacquer due to the hardness and toughness of the film, but an accurate estimate of the actual saving would be difficult to make.

A brief description of the lacquer used on Frisco equipment may be of interest. Manufactured by E. I. du Pont de Nemours Company, Inc., Parlin, N. J., it consists in general of nitrocotton with a small percentage of other ingredients dissolved in special solvents, and a finely ground pigment to provide the color. It is in effect a finishing material used in place of color and varnish coats. When applied to a surface the solvents quickly evaporate, leaving a film which is tough and hard. While a paint or varnish film dries by oxidation, lacquer dries by evaporation and as soon as this action ceases a chemically inert and stable thin film of material has been deposited on the surface which does not check or braise and which wears subsequently by slow erosion only.

Paint shop operations speeded up.

One of the most important advantages secured by the use of lacquer on Frisco equipment is greater speed of application. Undercoats are applied in practically the same time by both systems, but the greater speed of the application of lacquer is such that the total time is only seven days for the complete refinishing of a passenger coach exterior from the surface out, as compared with 14 days or more with the previous finish. This enables the same amount of work to be done in the paint shop with only 50 to 70 % of the previous force. An example of how the work can be speeded up in an emergency was afforded recently when urgent need for two passenger cars in the Frisco paint shop at Springfield, Mo., unexpectedly developed because of a wreck on the road. These cars were primed and surfaced ready for application of the finish coats, were sprayed with two coats of Duco, lettered and delivered to the transportation department in eight hours.

The increased speed of application has materially reduced the demand for paint shop space. Another advantage, due to the rapid drying feature of lacquer, is that finishing work may be safely done on cars in the paint shop with only reasonable precautions against the circulation of dust in the air. Another feature of great importance is that variations in temperature and humidity cause practically no difference in the rate of setting of a lacquer film, while under certain atmospheric conditions paint shop work was greatly retarded due to slow setting of the former finish.

A large percentage of Frisco cars are refinished by the application of Duco over old undercoats. In such cases, the time required for refinishing is three to four days as compared with six or seven days by the former system. Patching of mechanically injured cars is made comparatively easy owing primarily to the fact that there is no oxidization or chemical change in lacquer, once hardened, and when a second coat is applied it unites with the first to make a single coat.

The interiors of 30 passenger cars are finished largely by spraying with lacquer, which saves the labor of rubbing down with pumice stone, formerly necessary to reduce the gloss of varnish finish. Owing to the time saved in spraying and the elimination of rubbing down the interior, a standard passenger car can be refinished with Duco on the inside in six days as compared with nine days with varnish. A combination of the spray and brush methods of application has given the best results on car interiors, large areas being sprayed and small areas and the junction between colors brushed. Trimmings can be applied to sash, doors and car interiors two hours after the application of the lacquer.

In addition to the equipment mentioned above, four Frisco 100 000-lb. steel hopper cars and one caboose car have been finished with lacquer. The caboose has been in service a

year, the finish showing no signs of deterioration. Lacquer is also used on Frisco car furniture, window curtains, imitation leather, linoleum aisle strips, steel hoppers, etc. Sash and doors are mounted on racks, the glass covered around the edges with a protective coating of soap and whiting, and lacquer sprayed on, with a substantial saving in time over former brush methods. A similar method is used in protecting the windows of locomotive cabs while being sprayed. The coating is readily removed from the glass with a knife after the application of the lacquer.

The methods followed by the Frisco in applying undercoats and finish lacquer coats follow specifications suggested by the manufacturer.

Use of lacquer on locomotives

On 29 November 1924, the first Frisco locomotive, No. 1294, was sprayed with lacquer and since that date 626 locomotives have been finished with this material. Experience has shown that compared with a life of former materials of 12 to 18 months, lacquer gives 18 to 24 months' average service. The cost of application is 30 % less and the cost of the material about 30 % more, leaving a substantial net saving due to the greater durability of the lacquer finish and more rapid preparation of the locomotive for service. As in the case of cars, this latter feature is due to the fact that lacquer dries quickly and does not interfere with completion of the many small jobs which must be handled promptly in preparing a locomotive for service.

All parts of the locomotive and tender are finished with lacquer except the smoke box, firebox, side sheets and engine and tender trucks. The usual practice is to use one painter with a spray gun on the running boards for finishing the upper parts of the locomotive and to have two on the ground to spray cylinder jackets, motion work, etc. Asbestos particles and dirt of all kinds are first blown off by compressed air and the lacquer is sprayed on with the usual spray guns. The tender is ordinarily finished and lettered in the tank shop and the cab in the cab shop, but all of the rest of the locomotive is sprayed during the noon hour. Mechanics can go to work on the locomotive almost immediately afterwards to perform any necessary finishing operations and in this way the painting causes no delay in getting the locomotives ready.

The use of lacquer has produced another marked advantage in connection with the cleaning of car equipment because the surface is hard and smooth and does not hold dirt and foreign material as readily as the varnished surface. As a result, cleaning costs are substantially reduced. Plain soap and water has been found to give best results in cleaning. Especially on interiors is the cleaning advantage noticeable and in this case soap and water or oxalic acid or other cleaning materials on varnished interiors produce a streaked effect and ruin the finish. Lacquer is not harmed and, in fact, improves in appearance.

In the period of 2 1/2 years in which lacquer has been used extensively on the St. Louis-San Francisco, there have been no indications of harmful results in health hazard, or fire risks.

[385 .15 (.54)]

6. — Indian railway progress.

(From *Engineering*.)

The report of the Indian State Railway Board for 1925-1926 is an interesting one, for during that year State management was given new development. The Great Indian Peninsula Railway was transferred to State management; about 340 miles of new line, including the Khyber Railway, were opened to traffic and the Delhi-Umballa Kalka Railway was purchased. Another great company line, the East Indian Railway, had just previously been taken over.

Until quite recently no capital expenditure exceeding Rs. 12 1/2 lakhs on new lines and Rs. 20 lakhs on open lines could be undertaken without reference to the Secretary of State in London. Arrangements have been made whereby the Government of India may now sanction expenditure up to Rs. 150 lakhs on both new

and existing lines. This sum, representing about £1 125 000, may now be spent without reference to London, a state of affairs which indicates that considerably more latitude will be possible in planning.

Two further important changes in the administration are to be recorded : the separation of the audit and account staffs, so that the auditor-general becomes responsible for audit duties alone; and the establishment of an experimental clearing house. The latter step has been under the consideration of the Indian Railway Conference Association for many years, but difficulties, such as the variety of the tariffs and the great distances involved, which stood in the way of what at first sight might seem to be a natural development, have hitherto prevented much progress being made. In 1925-1926, it was, for the first time, possible to place an audit officer on special duty to test the practicability of a method of clearance he had himself suggested, and if, as we hope, the experiment is justified, its ramifications will be extended.

Turning to the result of the year's working covered by the report, the monsoon proved to be short-lived in the north and weak in the Deccan. In the plains the aggregate rainfall was 4 % below normal, and the wheat crop, which is largely dependent upon the previous monsoon and winter rains, was 10 % below that in the previous year. There was, therefore, little or no movement for export. The result was that the goods revenue decreased by Rs. 200 000 lakhs, a deficiency which was only partially made good by a general improvement in the coaching traffic. The total route mileage increased from 38 270 miles to 38 579 miles, and the number of passengers from 577 345 400 to 599 034 800. The tonnage of originating goods traffic increased from 77 million 796 000 tons to 79 617 000 tons.

The advantages of separating the railway from the general finances of the country, which had been effected a few months earlier, began to be reflected in the operating results in the twelve months under notice, though the revenue, for the reasons we have just given, was not so high as in the preceding year. The total receipts were, in fact, Rs. 100.6 crores, as against Rs. 101.56 crores in 1924-1925, while the expenditure was Rs. 91.3 crores, as against Rs. 88.39 crores in 1924-1925. The surplus was therefore Rs. 9.27 crores, as against Rs. 13.16 crores in 1924-1925, of which nearly Rs. 5.5 crores were appropriated to the general revenues under terms of the convention, the balance being transferred to the railway reserve fund. As already mentioned, the decrease in the gross earnings was mainly due to a falling off in the goods traffic. It should also be noted that the increase in the working expenses was not real, but was due to the facts that during the previous year the railway companies were allowed to import stores required for working the State Railways without customs duties and that certain accounting adjustments were made. If these items are taken into account the working expenses in 1925-1926 were, it appears, really less than during the previous year.

As regards new construction and engineering works, by far the greater part of the 340 miles opened for traffic were on either the 5-ft. 6-in. or metre (3 ft. 3 3/8 in.) gauges. At the end of the financial year, a total of 2 446.6 miles of new lines were under construction, of which 1 016 miles are to be on the 5-ft. 6-in gauge and 1 115 miles on the metre gauge. The longest of these works is the 260-mile Raipur-Parbatipur section of the Raipur-Vizianagram Railway, though three other extensions comprise over 100 miles of railway. This activity is mainly due to the improved financial position which has resulted from the policy outlined above. In general terms, the new construction problem has been dealt with on the basis of examining the whole country by areas, which roughly correspond to those served by the separate railway administrations, and continuous programmes of survey and construction are being prepared. On railways with heavy programmes of construction, special chief engineers and staffs have been appointed to deal with the new work. The total mileage of the projects which the Railway Board had either sanctioned or were having investigated at the end of March 1926, amounted to between 6 000 miles and 7 000 miles. It is hoped that, when the arrange-

ments are in full swing, the total annual addition to the railway mileage will be about 1 000. The effect of these improved communications on the prosperity of the country can hardly fail to be considerable.

It may be noted that, as regards the northern part of the country, a policy of light broad-gauge railways has, we understand, been adopted. The intention is to build the lines as cheaply as possible, in the first instance, to take the lighter classes of stock, bringing them to a higher standard as traffic develops. Bridges, however, will anticipate future requirements to a somewhat greater extent. Such a policy has, of course, been in vogue in Australasia for a long while. As a somewhat unusual case, we may mention the construction, now proceeding, of the Khangra Valley line on a 2-ft. 6-in. gauge. This is being built primarily to serve in the construction of a large hydro-electric scheme, but afterwards, it is hoped, it will become a paying line.

The increasing traffic on existing lines is, in certain cases, being dealt with by the employment of electric traction. This policy has already been carried to successful fruition on the Bombay suburban system, and is likely to be adopted shortly in the neigbourhoods of Calcutta and Madras. The feasibility of electrifying other portions of the South Indian Railways, and of using for that purpose energy generated by hydro-electric plant, is now being examined. Provision has also been made for the increased passenger traffic by ordering a number of steel coaches from abroad, which will have aggregate accommodation for 120 lower-class and 35 upper-class passengers. At Calcutta and Bombay, the traffic question is closely interlinked which that of providing better terminal facilities.

During 1925-1926, considerable preliminary work was done on the development of Vizagapatam as a major port. The first section of the work, which has been sanctioned, includes a wharf 1 500 feet long. This will be capable of taking three or four steamers. There will also be moorings for two vessels in the harbour and accommodation at the jetty for oil tankers or oil-burning steamers. The wharf will be constructed so as to give a depth of 30 feet below low water, while a channel, dredged to the same depth, will connect the harbour and the sea. The wharf will be provided with the necessary cranes and railway sidings. Work has already been started, not only on the harbour itself, but on the town-planning and water-supply schemes which are complementary to it.

As regards operation, passenger train miles showed an increase of over 5 % on both the broad and metre-gauges lines, while the goods train mileage decreased by nearly 6 % on the broad gauge and increased by 1.5 % on the metre-gauge sections. There was a general increase in the average passenger train speed from 19 to 19.5 miles per hour, and in the goods train speed from 8.97 to 9.58 miles per hour, the average loading of the goods trains increasing from 753.4 to 759.2 tons. On the other hand, the coal consumption of the passenger trains on the broad-gauge lines decreased by 2.84 %, and on the goods trains, on the same lines, by 0.7 %. The Railway Department is itself a mine owner, and 7 026 729 tons were raised from its pits during 1925-1926, a considerable proportion of which was, of course, used on the railways themselves. We understand that a regular fuel-conservation policy has now been embarked upon, while another interesting operating change has been the introduction of long engine runs. Successful efforts are being made to secure an increase in the punctuality of the passenger trains, and though a percentage of the order of 70 for trains arriving at the right time may seem low to British ideas, the fact that ten journeys of over 1 000 miles can be accomplished without a change may be put forward by way of explanation.

With regard to the standardisation of equipment, the statistics show that successful efforts are being made to overtake the arrears of former years. Standardisation has made such progress that drawings and specifications have been prepared, as a preliminary to ordering a number of engines of the new types for trial, while detailed drawings for a number of new types of « Indian State Railway » wagons, to supersede the present Indian Railway Conference Association Standards, have also been got

out. In the same way, after consultation with the principal interests concerned, a standard design for broad-gauge carriage underframes and for 13 types of broad-gauge wagons and two new broad-gauge special wagons have been approved; instructions have also been given for the construction of six sample vehicles and under frames, so that they can be tried out in practice. The problem of standardisation on the engineering side is also under consideration, and sub-committees of a Standing Committee of Chief Engineers of Class I Railways have been appointed to deal with the permanent way, bridging and signalling, respectively. The main body will act as a link between the sub-committees and the Railway Board, and will have the important duty of ensuring that the work of standardisation is carried out on a progressive basis. The track and bridge sub-committees have already met, and, as is known, have made certain investigations. An analogous problem is that of organisation of the State Railway workshops, and in this connection we may recall the report of the committee, presided over by Sir Vincent Raven, which was appointed to go into this question. This report was commented on in our columns some time ago (1). It is, we understand, still receiving attention, and we trust that action upon it will not be long delayed.

With regard to the problem of converting rolling-stock for use with the automatic buffer coupler, to which we called attention in a previous article (2), it has been found that considerable alterations would be necessary in the underframes before this could be employed, and that it would be necessary both to obtain more accurate information, not only on these matters, but on the expenditure that would be involved. This is now being done. At the same time, experiments are being made with the various types of automatic coupler and transition devices available.

The increasing governmental control of the Indian railways has not been followed, as in the common belief it should have been, by large additions to the staff. The number of employees, in fact, fell from 745 216 in 1924-1925 to 741 860 in 1925-1926, in spite of the increase in the route mileage. The question of the recruitment and training of officers has been receiving much attention, the difficulties having been enhanced by the settled policy of Indianisation. On the Class I railways, the percentage of European officials fell from 76.23 in 1924-1925 to 73.36 in 1925-1926, while the percentage of European officials appointed was 60.3. A report, which has been prepared by the Railway Board and is now awaiting the approval of the Secretary of State, envisages the recruitment of Indians to the extent of 75 % of the vacancies in the cadres of the State-managed railways. Three main classes of staff have to be considered — civil engineers, mechanical engineers, and traffic and commercial officers. Candidates for all three classes must, the report suggests, be holders of certain specified degrees, and will also be required to compete in a qualifying examination. Successful civil engineering candidates will be appointed on three years' probation, during which they will undergo one year's practical training. At the end of that time, they will be required to pass a final practical examination. The course of training for the traffic candidates will be similar. A system of special apprenticeship is proposed for the mechanical engineer appointments. Selected candidates, who must have passed certain examinations, will undergo a three years' course in the workshops, followed either by a two years' course at the Bengal College of Engineering, or by two years' practical training in the running department. Thereafter, selected apprentices will be sent to England for two years' theoretical and practical training, after which they will be required to pass the examination of either the Institution of Civil Engineers or the Institution of Mechanical Engineers. If this course seems a little intensive, it should at least result in the production of a type of officer possessed of an excellent stock of knowledge. It is to be hoped that the officers so trained will be possessed of all the other desired qualities, since technical knowledge forms only one of many qualifications in this work.

(1) See *Engineering*. 1926, vol. CXXII, p. 636.

(2) See *Engineering*. 1925, vol. CXIX, p. 746.

But even if this policy be successful, the position, for the present, is not easy. Though the policy of Indianisation has been accepted, the percentage of European officers employed on the State-managed lines is still 56.1, partly owing to the extensive constructional programme and partly to the lack of qualified Indians. On the other hand, the percentage of Indians in the higher subordinate grades has risen from 69 % in 1924-1925 to 73.9 % in 1925-1926. Owing to this change of conditions, there is, at the present time, great difficulty in obtaining sufficient supervising staff, especially in such branches as boilermaking. In time, doubtless, some of these difficulties will be overcome by the provision of better training facilities, in which connection great interest attaches to the Railway Transportation School at Chandausi. This school has been established primarily to obtain increased efficiency in working by ensuring that the staff are fully instructed in the use of methods and apparatus, a condition which is a necessary corollary to the more extended employment of mechanical equipment. The foundation of the scheme is a series of « area schools », which will both train probationers and provide refresher courses for those already in the service. For the present, men on the traffic and commercial sides only will be instructed, and these will be divided into three groups, comprising such officials as stationmasters, goods clerks, and guards, respectively. An examination is the necessary conclusion to each course. Refresher courses must be successfully passed before promotion to a higher grade takes place, and these will be held at a central rather than at an area school. For the present, the school at Chandausi is fulfilling both these functions, premises which were once part of a district headquarters of the Oudh and Rohilkland Railway being available for the purpose. The classes are divided into « senior », « junior » and « area », and the equipment includes a complete 2 1/2-inch model railway, which is operated by electrically-driven locomotives. These locomotives are controlled by signal apparatus of 10 different types, complete with double and single-line block instruments, interlocked lever frames, signals, points, locking gear, etc. The locomotive and carriage school is fitted with apparatus for demonstrating the working of the vacuum brake, sectioned locomotive fittings, valve-gear models, and train-lighting apparatus. Great care is taken to make the pupils as comfortable as possible, and it is therefore gratifying to learn that great keenness is shown in the work, and that the percentage of failures is small. One of the complications is that it has been necessary to provide nine different kitchens for preparing the food, not to speak of separate messes for the accommodation of members of the numerous religions and castes. A similar signal school to that at Chandausi is controlled by the Madras and Southern Mahratta Railway.

On the mechanical side of the railways, a policy of arranging for expert men to tour the different works to suggest shop improvements is, we believe, meeting with success. The question of apprentices has been receiving the Board's attention, and the need of a uniform policy on this question is admitted.

Statistics show that this great system is operated at the expense of a number of accidents which, though large in comparison with those usual on the British railways, is small when considered on an absolute basis. A total of 377 passengers were killed in 1925-1926, while 1 323 were injured, the corresponding figures for railway servants being 402 and 3 323 respectively. No less than 2 139 other persons were killed, 1 647 of these being trespassers. Derailments and collisions both show a welcome decrease. A Safety First campaign, now being vigorously undertaken, will, it is to be hoped, lead to a reduction in the number of these mishaps. Use is being made both of local advisory committees and of the kinematograph to increase the interest of the public in railway matters. That the system generally is one about which there is little reason to complain, and that the officials are taking every step to maintain and even improve the present standard, is, we think, abundantly clear.

[385. (06.111]

2 APPENDICES :

1. **List of the Members the Permanent Commission.**

2. **List of questions for the eleventh session.**

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

Meeting of the Permanent Commission held on the 9 July 1927.

The Permanent Commission of the International Railway Congress Association met on the 9 July 1927 at the Headquarters Office of the Belgian National Railway Company at Brussels, the President, Mr. E. Foulon, being in the chair.

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The President paid a tribute to the memory of Mr. Emile Heurteau, a former member of the Permanent Commission who had died since the last meeting of the Commission.

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I. — The meeting proceeded to nominate as members of the Permanent Commission :

Messrs. J. Castiau, Director general of the Control Services, Chief of the Secretariat of the Minister of Railways, Marine, Posts, Telegraphs, Telephones and Aeronautics of Belgium ;

Messrs. H. Hunziker, Engineer, Divisional Director of the Swiss Federal Posts and Railways Department ;

C. W. Hurcomb, C. B., C. B. E., Secretary, Ministry of Transport, Great Britain ;

N. Le Roux, Director general of the French State Railways ;

A. Schrafl, President of the General Direction of the Swiss Federal Railways ;

R. Schwob, Director general of the Railways at the French Ministry of Public Works ;

and Sir Josiah Stamp, G. B. E., D. Sc., President of the Executive, London Midland & Scottish Railway.

Mr. Lamalle, Director of operation, Belgian National Railways, and Mr. Javary, Director of Operation, Northern of France Railway, members of the Permanent Commission, have been nominated : the

former, Vice-President of the Commision, and the latter, member of the Executive Committee.

The new composition of the Permanent Commission is given in appendix I.

* * *

II. — The statement of receipts and expenditure for the year 1926, having been certified by an auditor, was approved, as was the provisional budget for the year 1927.

The variable part of the annual subscription paid by participating administrations (article 17 of the statutes) was fixed at 0.10 gold franc per kilometre for the current year 1927.

* * *

IV. — The next session will be held in Madrid during the first half of 1930.

The list of questions to be discussed at this session was agreed (see appendix II) and the provisional distribution between the different countries of nominations as reporters was also made.

* * *

III. — The following admissions and resignations have occurred since the last meeting:

GOVERNMENTS.

The Bulgarian Government has joined the Association.

ORGANISATIONS.

The Italian Transport Federation, which had been a member of the Association, has ceased to exist, and has been replaced by the « Confederazione Nazionale Fascista dei Trasporti Terrestri e della Navigazione Interna » (National Fascist Confederation of Land Transport and Internal Navigation) which has become a member on behalf of the four following federations:

Federazione Nazionale delle Ferrovie concesse (National Federation of Railways in Concession);

Federazione Nazionale delle Tramvie concesse (National Federation of Tramways in Concession);

Federazione Nazionale dei Trasporti meccanici (funiculaires et telepheriques) (National Federation of Mechanical Transport [Funicular and Telpher Lines]);

Federazione Nazionale dei Trasporti Municipalizzati (National Federation of Municipal Transport).

ADMINISTRATIONS.

Admissions:

Belgian National Railway Company (4 728 kilometres = 2 938 miles) which has taken the place of the Belgian State Railways.

	Kilom.	Miles.
Japanese State Railways.	12 644	7 856
Öxelösund-Flen-Vastmanlands Railway	300	186

Negotiations are in hand in connection with the admission of the Bulgarian State Railways (2 285 km. [1] = 1 420 miles).

Resignations:	Kilom.	Miles.
Frövi-Ludvika Railway . .	98	61
Norrköping - Söderköping Railway.	102	63
Mellersta - Östergötland Railway.	125	78
Liverpool - Overhead Railway.	12	7
Delaware, Lackawanna and Western Railroad. . . .	1 579	981
New York, Chicago & St. Louis Railroad	2 728	1 695

The Railway Congress Assosiation consits at the present time of 224 Administrations with a total length of 517 810 kilometres (321 758 miles) of line.

The General Secretary,
P. GHILAIN.

The President,
E. FOULON.

[1] The Bulgarian State Railways have now joined the Association (1 October 1927).

LIST OF MEMBERS OF THE PERMANENT COMMISSION

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

President :

E. **Fouion** (2), directeur général de la Société Nationale des chemins de fer belges ; rue du Progrès, 74, Brussels.

Vice-presidents :

C. **Colson** (1), membre de l'Institut, inspecteur général des ponts et chaussées, vice-président du Conseil d'État de France ; rue de Laplanche, 2, Paris ;

U. **Lamalle** (1), directeur de l'Exploitation à la Société Nationale des chemins de fer belges ; rue de Louvain, 17, Brussels.

Members of the Executive Committee :

G. **Behrens** (2), director, London Midland & Scottish Railway ; Chepstow street, 20, Manchester ;

The Right Hon. Sir Evelyn **Cecil** (3), G. B. E., M. P., privy councillor, director, Southern Railway (Great Britain) ; Cadogan Square, 2, London, S. W. 1 ;

P. E. **Javary** (3), directeur de l'Exploitation de la Compagnie du chemin de fer du Nord français ; rue de Dunkerque, 18, Paris.

Ex-presidents of sessions, members ex-officio :

The Right Hon. Viscount **Churchill**, G. C. V. O., chairman, Great Western Railway (Great Britain) ; Paddington Station, London, W. 2 ;

R. **de Corné**, ingénieur, président du conseil supérieur des travaux publics d'Italie ; Rome.

Members :

R. H. **Aishton** (2), president, American Railway Association ; South Dearborn Street, 431, Chicago, Ill. ;

T. A. **Alstrup** (2), directeur général des chemins de fer de l'État danois ; Gl. Kongevej 1, Copenhagen ;

W. W. **Atterbury** (3), president, Pennsylvania Railroad System ; Broad Street Station, Philadelphia, Pa. ;

G. **Behrens** (already named) ;

Sir Ernest Albert Seymour **Bell** (2), Kt., C. I. E., member of the Boards of Directors, Bengal-Nagpur and South Indian Railway Companies ; Brooklands, Cobham (Surrey, England) ;

A. **Braem** (2), conseiller à la Direction générale de la Société Nationale des chemins de fer belges ; rue de Louvain, 17, Brussels ;

J. **Castiau** (1), directeur général des services de contrôle, chef de cabinet de M. le Ministre des chemins de fer, marine, postes, télégraphes, téléphones et aéronautique de Belgique ; rue de la Loi, 17A, Brussels ;

H. **Caufriez** (3), directeur général de la Société nationale belge des chemins de fer vicinaux ; rue de la Science, 14, Brussels ;

The Right Hon. Sir Evelyn **Cecil**, G. B. E., M. P., (already named) ;

The Right Hon. Viscount **Churchill**, G. C. V. O. (already named) ;

C. **Colson** (already named) ;

R. **de Corné** (already named) ;

(1) Retires at the 11th session. — (2) Retires at the 12th session. — (3) Retires at the 13th session.

Sir Francis **Dent** (2), C. V. O., director, Southern Railway (Great Britain); Porthyfelin, Holyhead;

A. **Fabris** (3), ingénieur, chef du service du matériel et de la traction des chemins de fer de l'État italien; Villa Patrizi, Rome;

F. **Fiori** (3), administrateur des chemins de fer de l'État italien, Rome;

M. **Fontaneilles** (1), inspecteur général des ponts et chaussées, président de la section des chemins de fer au Conseil général des ponts et chaussées de France; rue de Sèvres, 4, Paris;

E. **Foulon** (already named);

Sir Henry **Fowler** (1), K. B. E., chief mechanical engineer, London Midland & Scottish Railway; Derby.

A. **Frank** (3), ingénieur des ponts et chaussées, inspecteur au Ministère des Chemins de fer de Pologne; Warsaw;

P. **Ghislain** (1), ingénieur principal au service du matériel de la Société Nationale des chemins de fer belges; rue du Progrès, 74, Brussels;

Sir Guy **Granet** (1), G. B. E., chairman, London Midland & Scottish Railway; Lombard Street, 80, London, E. C. 3;

A. **Granholm** (1), directeur général des chemins de fer de l'État suédois; Stockholm;

H. **Hunziker** (3), ingénieur, directeur de la division des chemins de fer du département fédéral des postes et des chemins de fer suisses; Berne;

C. W. **Hurcomb** (3), C. B., C. B. E., secretary to the Ministry of Transport (Great Britain); Whitehall Gardens, 6, London, S. W. 1;

A. **Jacques** (3), directeur de la Voie à la Société Nationale des chemins de fer belges; rue de Louvain, 17, Brussels;

P. E. **Javary** (already named);

E. **Kejr** (2), ingénieur, conseiller des constructions du département V/1 au Ministère des Chemins de fer de Tchécoslovaquie; Prague.

G. **Kunz** (3), administrateur-délégué du Chemin de fer Berne-Lœtschberg-Simplon; Berne;

U. **Lamalle** (already named);

N. **Le Roux** (2), directeur général des Chemins de fer de l'État français; 20, rue de Rome, Paris;

L. F. **Loree** (2), president, Delaware & Hudson Railroad; Nassau Street, 32, New York City;

A. **Mange** (3), administrateur de la Compagnie du chemin de fer de Paris à Orléans; rue de la Bienfaisance, 42, Paris;

M. **Margot** (2), directeur général de la Compagnie des chemins de fer de Paris à Lyon et à la Méditerranée; rue Saint-Lazare, 88, Paris;

E. **Maristany** (2), marquis de l'Argentera, directeur général de la Compagnie des chemins de fer de Madrid à Saragosse et à Alicante; Estación de Atocha, Madrid.

G. **Mereutza** (1), sous-directeur général des Chemins de fer roumains; Bucarest;

G. **Molle** (3), secrétaire technique à la Direction générale de la Société Nationale des chemins de fer belges; rue de Louvain, 17, Brussels;

C. **Oddone** (2), directeur général des Chemins de fer de l'État italien; Rome;

J. R. **Paul** (2), directeur de la Compagnie des chemins de fer du Midi français; boulevard Haussman, 54, Paris (IXe);

G. **Philippe** (2), inspecteur général des lignes Nord belges; Liége;

P. **Riboud** (1), directeur de la Compagnie des chemins de fer de l'Est français; rue d'Alsace, 21, Paris;

A. **Schrafl** (1), président de la Direction générale des Chemins de fer fédéraux suisses; Berne;

R. **Schowb** (1), directeur général des chemins de fer au Ministère des Travaux publics de France; 241, boulevard Saint-Germain, Paris;

Abdul-Hamid Pacha **Soliman** (1), directeur général des Chemins de fer, télégraphes et téléphones de l'État égyptien; Cairo;

Sir Josiah **Stamp** (1), G. B. E., D. Sc., president of the Executive, London Midland & Scottish Railway; Euston Station, London N. W. 1;

J. J. **Stieltjes** (2), inspecteur général au Service de la surveillance des chemins de fer des Pays-Bas; the Hague;

Sir Henry W. **Thornton** (2), chairman and president, Canadian National Railways; Montreal, Que.;

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(1) Retires at the 11th session. — (2) Retires at the 12th session. — (3) Retires at the 13th session.

Tsang Ou (1), directeur général adjoint du Chemin de fer du Lunghai (China) ; rue de Mogador, 5, Paris ;

A. **Valenciano y Mazerès** (1), ingénieur en chef des ponts et chaussées, sous-directeur général des travaux publics et chef de la section des chemins de fer au Ministère du fomento (Spain) ; Calle de Piamonte, principale derecha, 14, Madrid ;

Sir Ralph Lewis **Wedgwood** (3), C. B., C. M. G., chief general manager, London & North Eastern Railway ; King's Cross Station, London, N. 1 ;

D. **Willard** (3), chairman of the Board, American Railway Association ; president, Baltimore & Ohio Railroad ; Baltimore, Md. ;

N... (3), (Italy) ;

N... (1), (Japan).

Administrative Councillor : A. **Braem** (already named).

SECRETARY'S OFFICE : rue du Progrès, 74, Brussels.

General Secretary : P. **Ghilain** (already named).

Secretary-Treasurer : J. **Habran**, directeur d'administration honoraire des Chemins de fer de l'État belge ;

Assistant secretaries : R. **Desprets**, ingénieur principal à la Société Nationale des chemins de fer belges ;

E. **Minsart**, ingénieur principal à la Société Nationale des chemins de fer belges.

(1) Retires at the 11th session. — (2) Retires at the 12th session. — (3) Retires at the 13th session.

QUESTIONS

for discussion at the Madrid session (1930).

SECTION I : WAY AND WORKS.

I. — The use of concrete and reinforced concrete on railways.

A) Investigation into the respective merits of the different designs of concrete sleeper.

B) Concrete and reinforced concrete buildings.

II. — Resistance of rails against breakage and to wear.

A) First causes of rail breakage ; measures taken to reduce the number of breakages, both as regards the way rails are used and the conditions of inspection.

B) Quality of metal used for rails to give normal wear. Conditions governing manufacture and inspection.

Rails : profile and quality, length, weight, and cross section of the rails.

C) Rails joints. The most economical and efficient design.

III. — Investigation into the static and dynamic stresses in railway bridges.

IV. — Recent improvements in permanent way tools, and in the scientific organisation of maintenance work.

SECTION II : LOCOMOTIVES AND ROLLING STOCK.

V. — Locomotives of new types ; in particular, turbine locomotives and internal combustion motor locomotives.

Construction, efficiency, use and repair.

VI. — Improvements in the steam locomotive.

Increased pressures and higher superheats. Improvements in the design of superheaters and parts connected with superheating. Feed water heating and air preheating. Improvement of valve gears.

VII. — Electric locomotives for main line traction.

a) passenger locomotives ; *b*) goods locomotives ; *c*) locomotives for mountainous country. Multiple unit traction.

VIII. — All steel coaches. — Comparison with vehicles built of wood.

SECTION III : WORKING.

IX. — Relations between railways and sea ports.

Lay-out of maritime stations ; arrangement of outer and inner basins so that the most efficient lay-out of sidings may be provided for working them ; operating and rate fixing methods ; loading and discharging appliances.

X. — Methods to be used in marshalling yards to control the speed of vehicles being shunted, and to ensure they travel on to the lines in the various groups of sidings.

XI. — Signalling of lines for fast traffic and in main stations. Daylight signals. Automatic block system.

XII. — Economical traction methods for use in particular cases, as for example :

A) Organisation of train services on the minor lines of the large systems carrying little traffic, and of little used trains on the more important lines of these systems.

B) Use of special tractors for shunting in smaller yards and for certain work in large yards.

SECTION IV : GENERAL.

XIII. — Competition of road transport.

Effect of road competition on goods and passenger traffic and the best methods of meeting such competition, both as regards the main lines and the branches.

XIV. — Use in railway work of machines for simplifying statistical and accountancy work.

XV. — Co-operation of the staff towards increased efficiency and its participating in the profits.

XVI. — Methods followed in training of staff, professional, technical and ordinary working grades.

SECTION V : LIGHT RAILWAYS AND COLONIAL RAILWAYS.

XVII. — Penetration railways.

Construction :

a) Penetration railways in new countries.

b) Feeder railways in all countries.

XVIII. — Improvements in the permanent way equipment of light railways.

XIX. — Electrification of secondary lines.

XX. — Rail motor vehicles.

NEW BOOKS AND PUBLICATIONS

[656 .256.3 (.73)]

AMERICAN RAILWAY ASSOCIATION (A. R. A.). Signal Section. — **American Railway Signaling. Principles and practices. — Chapter VI : Direct Current Relays** — A book (6 × 9 inches) of 42 pages with figures. — 1927, New York, N. Y., Signal Section, A. R. A., 30, Vesey Street.

This book is the first of a series of twenty-six of which the American Railway Association has announced the publication. The whole series will form a complete study of signalling for instruction purposes. The editing was given to a committee formed from the Signalling Section of the American Railway Association itself.

The importance of the work will not be lost on railway engineers, especially those who are interested in the many special problems in signalling. For these it will be found a valuable source of information.

The relay is essential to the successful operation of many signalling installations, principally that of the automatic block system. As is known, this system works by means of continuous or alternating current track circuits.

The chapter just published deals with continuous current relays. It describes in detail the different types such as neutral relays, polarised relays, motor relays, etc. It then gives particulars of the way they should be made, the conditions of working they should meet, the tests they should undergo, and all information on their upkeep and inspection.

E. M.

[625 .245]

AMSLER (ALFRED J.) & Co. — **The Railway Dynamometer Car.** — A pamphlet (12 1/2 × 9 3/4 inches of 32 pages, with 48 figures. — 1927, Schaffhouse, The Kuhn Co's Printing Works.

Many railway companies own a dynamometer car. It is used to determine the resistance of trains, to make brake tests, and to measure the drawbar pull and power of both steam and electric locomotives.

The Amsler Company are well known as having specialised in the manufacture of the measuring devices used in railway dynamometer cars. The firm has had the good idea of publishing a pamphlet describing the apparatus they have designed and built, with particulars of the latest improvements realised.

The reader will find in this small work particulars of the special layout of vehicles fitted for use when making dynamometric tests. He will also find full information on the equipment of modern dynamometer cars, and in particular :

the hydraulic dynamometer arranged to measure both pull and buffing loads;

the spherical speed recorder;

the ergometer or apparatus for measuring acceleration forces;

the apparatus measuring the work developed at the draw bar hook;

the apparatus indicating and recording the instantaneous power developed at the draw hook;

the anemometer measuring the wind pressure and indicating its direction in relation to that of the train;

the brake dynamometer for measuring the brake power and recording the different phenomena occurring during braking;

the apparatus recording the relative movements of different parts of the vehicle.

The theory of the ergometer, of the spherical speed recorder and of the apparatus for measuring the work and power at the draw hook is dealt with very completely.

The pamphlet is well illustrated and contains many plates illustrating the apparatus and others reproducing diagrams taken during test runs.

E. M.